PRINCIPLES OF INDUSTRIAL MANAGEMENT

Fred. W. Taylor
Past President of the American Society of Mechanical Engineers and
Pioneer in Scientific Management

Frontispiece

PRINCIPLES OF INDUSTRIAL MANAGEMENT

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FOURTH EDITION

TORONTO
SIR ISAAC PITMAN & SONS (CANADA), LTD.

SIR ISAAC PITMAN & SONS (CANADA), LTD.
(INCORPORATING THE COMMERCIAL TEXT BOOK COMPANY)
PITMAN HOUSE, 381-383 CHURCH STREET, TORONTO

ASSOCIATED COMPANIES
SIR ISAAC PITMAN & SONS, LTD.
PITMAN HOUSE, PARKER STREET, KINGSWAY, LONDON, W.C. 2
THE PITMAN PRESS, BATH
PITMAN HOUSE, LITTLE COLLINS STREET, MELBOURNE
UNITEERS BUILDING, RIVER VALLEY ROAD, SINGAPORE
27 BECKETTS BUILDINGS, PRESIDENT STREET, JOHANNESBURG
PITMAN PUBLISHING CORPORATION
2 WEST 45TH STREET, NEW YORK
205 WEST MONROE STREET, CHICAGO

Printed and Bound by
The Hunter-Rose Co. Limited, Toronto

PREFACE TO THIRD AND FOURTH EDITIONS

MORE new material and recent references have been added.

The assistance of Mr. T. C. Graham, B.A.Sc., in providing material for Chapter XII is gratefully acknowledged.

E. A. ALLCUT.

TORONTO,
December 1941 *and June* 1947.

PREFACE TO SECOND EDITION

THE recent industrial depression was responsible for the publication of a large number of papers dealing with the philosophy and problems of management.

New material obtained from these papers has been added to the text, and in cases where it was impossible to deal with the subject adequately in that way, references to the original papers have been made. The original purpose of this book was to compress as much information as possible into a small volume, and in introducing new matter, that policy has been followed. Additional illustrations have been provided where experience has shown them to be desirable.

E. A. ALLCUT.

TORONTO,
June, 1937.

PREFACE TO FIRST EDITION

THIS book was written for use by students as a text and, for this reason, no attempt has been made to describe the details of industrial administration. Such examples as have been included are designed rather to illustrate principles than to serve as copies. The various forms and cards that are used in management or production work are prepared for specific purposes and differ considerably as to detail, even in different factories engaged on the same work. Copies of such forms, therefore, have only been included in special cases, where the author considered that a definite illustration, however specialized it might be, was better than none at all. Although this treatise was designed for students' use, it is hoped that it may also be of some service to those engaged in the engineering industries, who wish to obtain some general knowledge of the principles of management. As most of the author's experience has been gained in mechanical work, it is natural that many of the illustrations have been drawn from this branch of engineering, but an attempt has been made to treat the subject generally, so that students in other branches may derive some benefit therefrom.

The author's thanks are due to those firms, societies, and individuals who have given permission to reproduce photographs and extracts from their publications, and particularly to the American Society of Mechanical Engineers, from whose Transactions much information has been abstracted.

E. A. ALLCUT.

TORONTO,
July, 1932.

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CHAPTER I

MAINLY HISTORICAL

Introduction.

No treatise on Industrial Management is complete without some reference to its historical background. The importance of this is well indicated by Lansburgh[1] in the following paragraph: "One of the most frequent causes of poor management and accompanying business ineffectiveness is the tendency to overemphasize conditions which may exist at any given time. Even a brief study of industrial history helps to prevent glorification of the present and aids the executive to vision better the future policies of his enterprise." What has happened in the past is frequently an indication of what is likely to occur in the future, and the study of historical events often indicates the reasons for present conditions, and makes them appear in proper perspective.

Civilization is described as "reclamation from barbarism," and this re-arrangement of life is largely the work of the engineer. The various phases of social change are defined by Usher[2] as—

1. Technological changes.
2. Development of the consequences.
3. Revisions of law or custom.

The early history of industry, therefore, is not a thing apart, but follows closely the political and social histories of the peoples, as the tools they used, their weapons and means of defence, their sanitation and transport, affected most of their daily lives. This aspect of industrial history has been described in detail elsewhere[3] and will only be referred to in the following pages in a general way.

Kimball[4] says that "the total wealth that any people can create is governed primarily by two factors—

1. The natural resources of the country that they inhabit.
2. The tools of production, mental and physical, available for developing those resources."

[1] *Industrial Management*, 1928, p. 6.
[2] *A History of Mechanical Inventions*, 1929, p. 6.
[3] *Engineering's Part in the Development of Civilization*, Dugald Jackson, 1939.
[4] *Principles of Industrial Organization*, 1939, p. 2.

As a corollary to these, he adds that: "Highly developed tools of production make *possible* a high average state of mental development and physical comfort; but the *realization* of this average depends upon national ideals and the social and industrial organization for the distribution of wealth."

The object of industry is to create wealth or to add value to raw material by changing its form, or its properties. This implies the division of industry into two main branches—

(*a*) Manufacture or production.
(*b*) Sales and distribution.

The second function bears some relation to the first, as it is useless to produce merchandise that cannot be sold, or to make greater quantities than the market can absorb. Apart from these modifying influences, questions of distribution and sale do not come within the scope of this book, and so will not be considered in detail. Many engineers, however, are now entering the sales side of industry where their technical training can be of considerable advantage.[1]

Sales engineers can, and very frequently do, make important contributions in the design of equipment and have saved thousands of dollars for the customers of their firms. They have been instrumental in the development of new products for their companies and for new uses of old products. On the other hand, sales engineering, if allowed to run loose, may cost the organization thousands of dollars which never can be recouped. For example, consider a highly standardized line of equipment that is being manufactured almost on a mass-production basis and at a low margin of profit. The net profit available for dividends depends almost entirely upon the volume of production. This volume may very easily be upset and the profit eliminated by the injection into the manufacturing schedule of modifications of this standard equipment or by the attempt to design and build special equipment with which to meet the peculiar needs of a particular customer.[2]

Handicraft.

The development of craftsmanship was characterized by the construction of primitive tools made successively of flint, bronze, and iron, for the purpose of holding, manipulating, and shaping materials. Considering the crude nature of the facilities available, these indicated the possession of a high degree of skill by

[1] "Industrial Marketing," *Mechanical Engineering*, March, 1940.
[2] "Industrial Marketing," *Mechanical Engineering*, August, 1940, p. 621.

the makers. Simple machines were also made, enabling large civil and military constructions to be undertaken[1]; but in spite of the introduction of mechanism, practically all of the production before the eighteenth century was based on handicraft. Most of the industrial machinery was made of wood, instruments of precision only being made of metal. Comparatively little use was made of metals, as the chemistry of the metallic compounds was not sufficiently understood to enable their manufacture to be undertaken on a large scale.

Handicraft production was conservative and individual in character as compared with the progressive and collective nature of modern industry. This type of fabrication existed in several transitional forms which differed mostly in methods of distribution and sale.

The earliest of these was the *domestic* type, in which the various members of the household produced garments and other necessities to satisfy their own requirements, each family forming a self-contained unit, but these conditions existed only in very primitive society.

Division of labour took place at a very early date, each member of the tribe, or family, doing the work at which he was most skilful, and bartering the products of his industry for those of other craftsmen. Xenophon[2] in 375–370 B.C. indicated the extent to which this practice had developed in Greece—

"It is impossible for a man who is jack of many trades to do all things well. In large cities, because of the fact that many persons need each commodity, a single trade suffices for making a living, and often, not even one complete trade; but one workman makes men's sandals, another women's. One person makes his living exclusively by stitching sandals, another by cutting them out. One man is exclusively a cutter of garments. Another takes no part in this work but merely puts the pieces together."

Thus, if the size of the market were suitable, the workers might be, and in some cases were, gathered together into factories for facility in distributing the raw materials and collecting the finished goods. It is stated that, in the Middle Ages, Jack of Newbury had a factory employing 1000 persons. Such factories, however, were different in principle from those of the present

[1]See *The Quest for Power*, Vowles.
[2]See Alford, "Laws of Manufacturing Management," *A.S.M.E.*, 1926.

day, as they were still based on handicraft, and did not represent any marked change in methods of manufacture.

Durant[1] describes the "ergasteria" of Athens in the age of Pericles (about 450 B.C.), including a shield factory having 120 men, a shoe factory with 10, a cabinet factory with 20, and an armour factory with 30. These factories at first produced to order, then for the home market and later for export. Each was an independent unit, being operated mostly by slaves, so that there was no incentive to develop machinery. In one century Athens moved from domestic economy, through urban economy to international economy.

In other cases, the raw materials were distributed to the cottages of the workers, and the finished products were collected by the merchant who disposed of them. Thus, the worker had no contact with the ultimate consumer, this being effected by the agent or middleman.

James Nasmyth[2] (1808–1890), the inventor of the steam hammer, describes a conversation with William Stubbs, a celebrated file maker of Warrington. He stated that he had no factory, but served out the requisite quantities of cast steel to the workmen and they forged the metal into files of all kinds in their own cottage workshops. The industry started shortly after the Norman Conquest when the Master of Arms, Hugo de Lupus, commenced the manufacture of armour and weapons in Cheshire. When the use of armour was discontinued, owing to the employment of gunpowder, the skill attained by the workers in the manipulation of iron was diverted to more peaceful applications.

National ideals, or local custom in some countries (as in India), tended to restrict certain classes of labour to individual castes or classes. The Romans, for instance, had a regulation whereby the Armourers were a class set aside for this particular industry.

> Labor was "frozen" to its job, forbidden to pass from one shop to another without governmental consent. Each "collegium" or guild was bound to its trade and its assigned task, and no man might leave the guild in which he had been enrolled. Membership in one guild or another was made compulsory on all persons engaged in commerce and industry; and the son was required to follow the trade of his father. When any man wished to leave his place or occupation for another,

[1] *The Life of Greece*, Durant, pp. 271–2, 1939.
[2] *The Autobiography of James Nasmyth*, 1931, p. 69.

the state reminded him that Italy was in a state of siege by the barbarians, and that every man must stay at his post.[1]

During the Middle Ages, the principal industries were controlled by the craft gilds, the objectives of which were efficiency in workmanship and trustworthiness in the sale of their products.[2] Each gild was composed of masters, journeymen, and apprentices, the duration of apprenticeship varying from five to seven years. It regulated the quantity and quality of goods for sale, the markets at which they were sold, the hours of work, and rates of pay. The number of apprentices was limited in some cases, and the conditions of work were controlled by the gild. Assistance was rendered in cases of unemployment or sickness, and provision was made for widows and children of deceased members.

These gilds were originally formed, before the Norman Conquest, for mutual protection and, when a member was killed or died, provided masses for his soul. Eventually, they became religious gilds, helping members in times of misfortune, and so were the equivalent of the modern benefit society. Then came the merchant gilds, each of which had a monopoly of buying and selling in its own town and was able to regulate selling prices. The craftsmen then banded together in a similar manner to control the quality and quantity of goods made for sale. Membership in a merchant gild was obtainable by a money payment, but craftsmanship could only be taught, hence the establishment of the apprenticeship system. Finally, the number of journeymen who had served their time as apprentices became so great that they, in turn, formed unions to obtain better wages or conditions for themselves. Thus, the craft gilds, controlled by the masters, were equivalent to federations of employers, while journeymen's unions were the forerunners of modern trade unions.

The development of capital and the expansion of trade, due to the discoveries and explorations of the fifteenth and sixteenth centuries, together with the growing power of national governments and the decay of feudalism, weakened the power of the gilds. They also suffered severe losses, due to confiscation of property during the Reformation, so that the regulation of industry gradually passed into the hands of the Governments.

[1] *Caesar and Christ*, Will Durant, p. 644. (Simon & Schuster). Reprinted by permission.

[2] "Gilds and Trade Companies," Dodds, *Heaton Works Journal*, 1937.

The Industrial Revolution.

In the latter part of the eighteenth century, a number of inventions or developments took place in Great Britain, resulting in the gradual supersession of handicraft and its replacement by machinery. These changes first took place in Great Britain, because at that period it was a highly-centralized power, with political security for the investment of capital,[1] had a strong banking system, and had fostered its shipping, thereby advancing its foreign and colonial trade.

The inventions which were primarily responsible, consisted of four in the textile industry, namely—

The spinning jenny by James Hargreaves, 1770.

The water frame by Richard Arkwright, 1771.[2]

The mule by Samuel Crompton, 1779.

The power loom by Edmund Cartwright, 1785.[3]

About the same time (1781–82), the ingenuity of James Watt transformed the steam engine from a pumping unit to one producing rotary motion, and greatly improved its details and economy. This made large supplies of power readily available for the new machines, and gave a wider choice of location. The work of Watt and others, however, was also dependent on contemporary improvements in metallurgical science and machine tool construction. The development of the puddling process by Cort in 1784 considerably increased the output of iron, while Darby and Réaumur had made commercial ironfounding possible on a large scale, early in the same century. About 1776 Wilkinson had improved the boring machine so that engine cylinders could be machined accurately, and had applied the steam hammer for making heavy forgings, while Maudslay produced an all-metal lathe with slide rest in 1794, and a screw-cutting lathe in 1800.[4]

The earliest reference to interchangeable manufacture was made by Jefferson in 1785, when he described his visit to a French workman, named Le Blanc, who had produced fifty musket locks with interchangeable parts. Whitney and North applied this process on a large scale in 1800 to the manufacture of firearms in America, and other branches of industry gradually followed their lead.[5]

[1] *Evolution of Industrial Organization*, Shields, p. 16.

[2] See *Mechanical Engineering*, October, 1932, p. 677.

[3] Details of these machines are given in Usher's *History of Mechanical Inventions*, Chap. IX.

[4] *Autobiography of James Nasmyth*, Chaps. IV and V.

[5] "Interchangeable Manufacture," Roe, *Mechanical Engineering*, October, 1937.

These inventions and developments all occurred during a comparatively short time (corresponding roughly with the period of the French Revolution, 1789–1815), and their application altered the whole character of industry. The change was not due solely to the use of machines, nor to the division of labour, for these existed before the Industrial Revolution, but to the introduction of two new principles, namely—

(a) *The transfer of skill* from the worker to the machine, and thus to the tool maker and designer, so that the accuracy of the work produced no longer depended mainly on the skill or craftsmanship of the operator. The law governing this change is stated by Alford[1] as follows: "*The attention and skill required to use a tool or operate a machine is inversely as the skill transferred into its mechanism.*" This involves the degradation of many skilled workmen into unskilled or semi-skilled machine minders. On the other hand, some are elevated to the skilled class of tool makers. America, with its extensive home market and high proportion of unskilled immigrants, had the first opportunity of applying this principle on a large scale, and was able to manufacture cheaply and in large quantities before the countries of Europe were in a position to do so. During the First World War, however, very large quantities of interchangeable materials were required in all countries, and the process of mechanization was enormously accelerated everywhere.

Hargreaves' first machine was destroyed by a mob, and riots took place at that time among the workmen who were displaced by machinery. This mental attitude is usually prevalent during periods of trade depression, when facilities for production cannot be used to the full; but on the whole, the increased use of machinery and all that it implies, has been justified by the wider field available for labour, by improvements in the general standard of living, and by lower costs of production, so that things formerly only obtainable by the wealthy, are now widely enjoyed.

The attitude of Canadian labour toward mechanization in the middle of the nineteenth century is illustrated by the following excerpt—

Nearly a hundred years ago, Toronto had its first strike. It was not brought about by long hours, poor wages, disregard of union rules, nor any of the familiar causes of present-day walkouts. A sewing machine caused the rumpus.

[1] "Laws of Manufacturing Management," *Trans. A.S.M.E.*, 1926.

In 1847, Walker and Hutchinson, King Street tailors, introduced a sewing machine into their workshop, and the working tailors in their employment, regarding the innovation as contrary to all time-honoured traditions of the craft, promptly rebelled and downed needles.

After a few days, Messrs. Walker and Hutchinson came to the conclusion that the men, after all, might be right. They handed the objectionable machine over to the workers to dispose of as they thought fit. To celebrate their triumph, the tailors carried the discarded sewing machine in a parade along King Street. It was then packed up and shipped back to the manufacturers in New York City.

And the same evening a banquet was provided by the firm of Walker and Hutchinson, to which all the happy needle plyers were invited.[1]

(b) *The transfer of ownership.* The increased cost of tools and the power required to operate them, made it impossible in most cases for the craftsman to own the facilities for production. He was obliged, therefore, to hire himself to the owner or capitalist as a machine operator. The latter was sometimes a craftsman, who, by skill and enterprise, had established himself as a worker-owner, and whose business gradually extended until he was unable to handle it all by himself, and had to delegate authority to others. As the personal contact between capital and labour became less, exploitation of labour increased, and this led to the formation of trade unions to protect the interests of the workers. Keen competition between businesses led to amalgamations, and national distribution began to supplant local marketing, so that some industries became practically monopolies, with autocratic and privileged executives. This led to a similar growth of labour organizations, so that Capital and Labour came into conflict on a large scale, frequently with great inconvenience to the public. Before the First World War, emphasis was placed on the mechanical part of the equipment, but the requirements during the War of great precision and maximum output with a minimum of skilled labour, brought about a readjustment of ideas. It was discovered that the well-being of the worker was more important than perfection of machinery and processes, and the human side of industry received considerable attention. Since that time, the study of "Industrial Relations" has received the constantly increasing attention of progressive management.[2]

Location and Transport.

The gild system was restricted, in most cases, to a certain radius round the town, and the domestic or commission system

[1]From Toronto "Evening Telegram," December 1, 1943.

[2]This phase is well summarized by Prof. J. W. Roe in "The Machine Age," *Mechanical Engineering*, April, 1930.

gradually became national in its scope, but the modern production system is world-wide. The early workers were hampered by poor means of communication; the roads were bad, and each town with its surrounding district, tried to be as self-supporting as possible, treating traders from other towns as foreigners and putting numerous obstacles in their way. Thus, in any district, a poor harvest meant deprivation and want in the adjacent towns, while no proper outlet was provided for the excess when the harvest was bountiful. Improvements in methods of transport and communication, and the reduced cost of transport, widened the possible markets and intensified competition. Railways, canals, and steamships enabled the various countries to export their surplus commodities to different nations, and to receive others in exchange. The improvement of roads has also brought motor transport into competition with the railroads and, in some cases, has caused them considerable embarrassment. More recently, the use of air transport has accelerated deliveries and has opened up new regions for industrial development. At the same time, means of communication by telephone, telegraph, and radio have facilitated communication between cities and nations. All of these factors have increased competition, made prices more uniform (save for the influence of tariffs), and enlarged the possible markets. They have tended, therefore, to accelerate the movement toward the increasing size of producing and trading units.[1]

Size of Organization.

The tendency of business to crystallize into large units has already been referred to as a natural consequence of the Industrial Revolution, but the reasons for this will now be considered in greater detail. Individual and partnership direction still exist in some small firms, but the progress and success of the enterprise are so dependent on the personal characteristics of the owner or partners, that large firms are seldom financed and handled in this way. Joint stock companies and corporations place the executive power and general policy in the hands of their boards of directors, so that control and ownership are separated from each other; the shareholders merely receive dividends, and take little interest in the management or policy of the business, unless the returns on their investment are unsatisfactory. This method of control facilitates continuity of

[1]See "The Communication Revolution, 1760–1933," by Prof. R. G. Albion, *Mechanical Engineering*, September, 1933, p. 531.

policy and direction, and makes practicable large-scale organization and production.

The application of this tendency toward aggregation is limited, to some extent, by the location of the business and the size of the market which can be supplied economically from that location, but, as indicated above, these factors are becoming less important as transport facilities increase.

The advantages of mass production may be summarized as follows—

1. Large firms can purchase material in great quantities, and so can obtain better terms in the form of discounts, rebates, and deliveries. At the same time they can command a greater uniformity of quality and dimensions, and thus can manufacture more cheaply. The ultimate tendency is to dominate the policy of the supplying firm, and finally to absorb it, and, in this way, the manufacturing organization becomes more self-contained.

2. When material is being manufactured in large quantities, the fixed or establishment charges become less per unit of output.

3. Special transport rates can be obtained, both for raw materials and for the finished product.

4. Middleman's profits or commissions may be eliminated.

5. Up-to-date machinery can be installed, giving cheaper production and better opportunities for producing standard interchangeable articles.

6. Waste or by-products may be used to better advantage.

7. Research laboratories may be maintained for the purpose of improving the firm's products, solving difficulties of manufacture, and indicating new fields of activity.

8. A better system of sales organization may be used, and more efficient advertising promoted.

9. A large firm is usually more powerful than a small one when legal and labour troubles occur.

These, and similar considerations, produced such organizations as the Standard Oil Company, United States Steel Corporation, General Electric and Westinghouse Companies, Bell Telephone, and General Motors Corporation, most of which are practically self-sufficing units and all are powerful combinations.

Many of the large British and American firms now have their own research laboratories for investigating problems in their particular line of activity. The workers in these laboratories contribute many papers to the technical societies and journals,

and in this way their labours have had a beneficial effect on industry as a whole.

Facts in support of this thesis are overpowering. Eighteen of the new industries which have grown directly out of scientific research within the average lifetime of those living to-day provide one-fourth of all the employment in the United States. The majority of the products now manufactured by electrical companies were unknown fifteen years ago. It is estimated that ninety-five per cent of our chemical industry is based on fundamental discoveries made in university laboratories. A report of the Brookings Institution outlines the basic procedure necessary for economic recovery as the application of scientific methods to improve quality and decrease cost of production and to develop new products. It says that the basic necessity is to encourage science, encourage capital, and remove the artificial restrictions of regulations. Even in agriculture, perhaps the oldest of man's arts, technology has created new markets by developing transportation and storage facilities, has met the threats of food shortage for expanding populations by technical improvements in soils, seeds and farming methods, and is seeking to develop new industrial uses for farm products in order to use the surplus which can now be produced.[1]

The large amount of capital at the disposal of such corporations, and the quantity of similar work which has to be performed, make it possible to use special jigs and automatic machinery that would be uneconomical for firms producing small quantities.

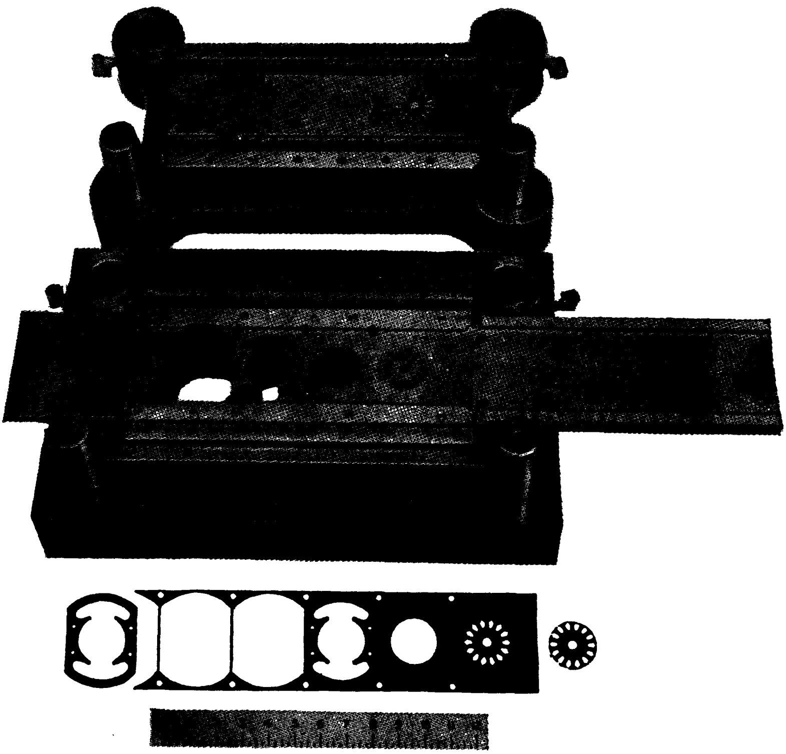
An illustration of this is given by Mr. W. J. Cameron,[2] who describes the machinery necessary for producing in large quantities the inner shell of the hub-cap of the Ford car. The press for stamping it cost $30,770 and the special dies for forming it $13,328. To these must be added the costs of power, factory space and maintenance. The cost of the tools necessary to make this article by hand would be about $24, but the automatic press produces 2160 caps in the time required by the hand worker to make one. Hence, *for the same rate of output* the cost of the tools required by the hand workers would be greater than that of the machine. Also, the press occupies 360 square feet, while the handworkers' benches would occupy 116,640 square feet. Produced by hand, the cost would be about $2.50 per article, whereas the present cost is a little over 12 cents.

Thus, the economy of providing labour-saving and automatic devices depends on the *quantity* of work to be done, and

[1] "The Influence of Technical Progress upon Social Development," Compton *Engineering Journal*, September, 1939.
[2] *Broadcast*, 13th February, 1938.

this is determined by the capacity of the market to absorb the product.

The rise of these large manufacturing corporations and the ever increasing size of selling organizations (chain stores) apparently indicate the ultimate extinction of small businesses.



(*Courtesy of Modern Tool Works Limited, Toronto*)

FIG. I.1. PROGRESSIVE LAMINATION DIE TO PRODUCE THE ROTOR AND STATOR FOR A SMALL ELECTRIC MOTOR

Murphy[1] says that, in the United States (*a*) 85 per cent of the cigarettes are sold by four manufacturers, (*b*) 90 per cent of passenger cars are sold by three firms, (*c*) 80 per cent of domestic dyes are made by four companies, and similarly for meat, yeast, soap, electrical goods, etc. Most of these have grown from small businesses having strong personalized direction. Large organizations suffer from lack of flexibility, being handicapped by large plant investments and overhead costs, and cannot afford to exploit new ideas as many of the smaller businesses can and do.

[1] *Harper's Magazine*, June, 1937.

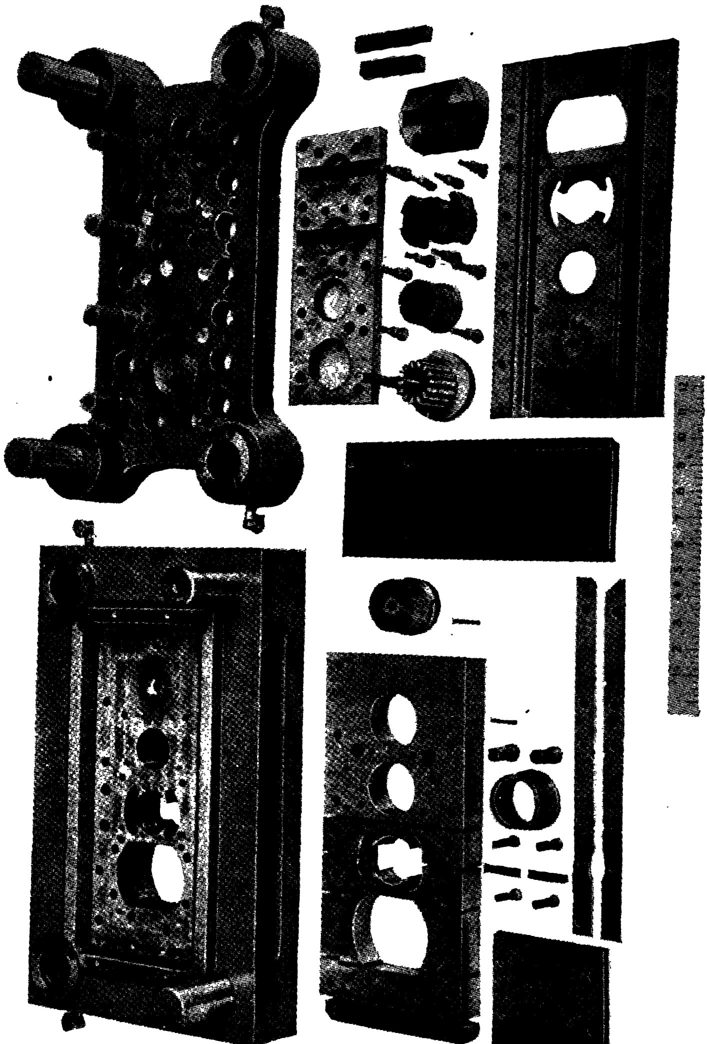
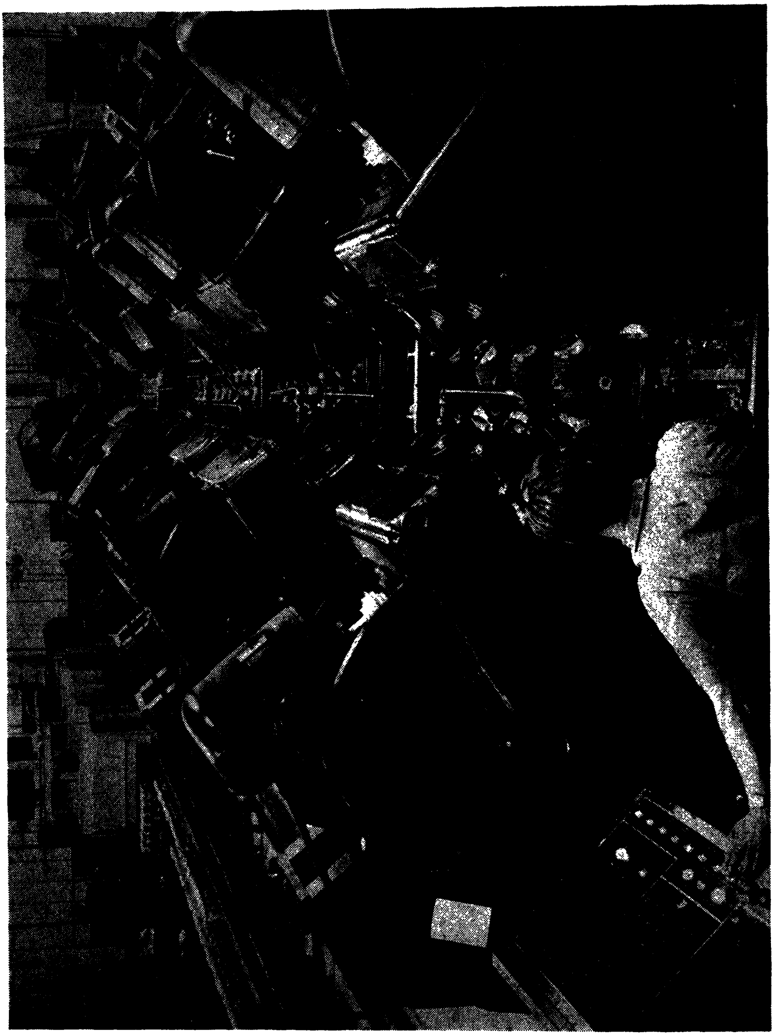


FIG. I.2. VARIOUS SECTIONS OF THE DIE SHOWN IN FIG. I.1 IN THEIR RELATIVE POSITIONS BEFORE ASSEMBLY



(*Courtesy of* Canadian Machinery)

FIG. I.3. GREENLEE AUTOMATIC MACHINE FOR MACHINING CYLINDER HEADS FOR AIRCRAFT ENGINES. (56 Stations)

There is now a very definite idea abroad that there are economic limitations to the growth in the size of manufacturing enterprises, and in large companies decentralization is now being practised to a considerable degree. Kimball[1] summarizes the situation as follows: "Indeed, if the facts were known, it probably would be found that many modern industrial enterprises have already passed the point of greatest efficiency and greatest economic returns. The value of the industrial product per worker in this country in 1900 was about $1600, while in 1919 (the last census in which such data are available) this ratio had risen to $7500. Making due allowance for the changed value of the dollar, this is a great gain in production per worker. But *the ratio of the value of products to the capital invested has decreased* steadily for a number of years. In 1850 this ratio was close to 2, but it fell progressively until in 1919 it was only 1.39. This would appear to indicate that even if the number of workers is materially reduced in favour of more refined machinery, the cost of production will eventually rise with increased complexity of mechanisms. This is already foreshadowed in some industries where the fully automatic machine as yet is not so economical as the semi-automatic operated by a skilled worker. Barring some new and eruptive change like the Industrial Revolution, there is little likelihood of startling changes in the immediate future."

[1] *Mechanical Engineering*, February, 1933, p. 89. See also *Engineering*, 10th August, 1934, p. 156.

CHAPTER II

SPECIALIZATION AND STANDARDIZATION

The laws of specialization and standardization, as defined by Alford, are—

1. *Concentrating upon the manufacture of a single or a few types and sizes of product tends to improve the quality and lower the production cost.*

2. *Interchangeable manufacture reduces manufacturing cost and, all other characteristics being equal, produces a product of maximum serviceability.*

Specialization.

This is the confinement of activity to a limited field, and is applied in two ways. The *division of work* or specialization of the *job* so that one, or a few manual or mental operations, are assigned to the worker, tends to improve the quality and increase the quantity of output. The specialization of the *individual* assigns each worker to one or a few operations which he is particularly able to perform, and this also improves both the quality and quantity of output. Essentially, specialization is *simplification*. The old engineering shops produced great varieties of work and were almost self-contained from a manufacturing standpoint. After a time, however, some of the smaller parts which were common to different machines were made by firms organized for this specific purpose, and it was found to be cheaper for the average firm to buy these articles than to make them. The essential factor in this process was the existence of a demand from various concerns making similar products for accessories of a given kind. Thus, the general purpose shop became to an ever increasing extent an assembling unit, many of the details being made elsewhere by firms specializing in those products.

This principle was gradually applied to the machine tools themselves, universal machines being superseded by single-purpose machines, or by automatic mechanisms in cases where the nature and extent of the work justified the capital expenditure. The variety of output, both from firms and from individual machines, was thus restricted to single types, and in many cases

to single sizes. The manufacture of shells and other war material by general engineering firms was a case in point. Many machine shops were stripped of their general-purpose machinery and equipped with single-purpose machines for this work. After the First World War these machines were scrapped in their turn and replaced by different machinery specially designed for the production of other things, such as automobiles.

While the advantages of specialization are evident, there is the danger that sudden changes or new inventions may leave highly-specialized firms stranded, as they have less vitality in times of depression owing to their dependence on some particular type of demand. The aggregation of manufacturing units into large corporations, however, gives to each constituent firm the backing of the others, if and when such difficulties arise.

Standardization.

Within the field of any specialized industry a large number of types and an infinite number of sizes are possible, so that it is necessary to standardize certain types and sizes to suit the average demand. Once these standards have been fixed, either by individual firms or by committees established for that purpose, mass production and interchangeable manufacture become possible. In the English-speaking countries, the principal national committees are—

(*a*) The British Engineering Standards Association (1901).

(*b*) The American Engineering Standards Committee (1918).

(*c*) The Canadian Engineering Standards Association (1919) re-named Canadian Standards Association (1944).

(*d*) The Australian Commonwealth Engineering Standards Association (1922).

Most of the other principal manufacturing countries have similar bodies, some of which are described in detail by Harriman.[1] In general, these committees are drawn from the various technical societies,[2] and have sectional and advisory committees to do the actual work, the main committees being co-ordinating and judicial bodies. Tentative standards are first drawn up by the sectional committees and are then published as such, so that the proposed standards may be subjected to the test of practical experience before being finally adopted and filed. Standardizing laboratories are also maintained, and several international con-

[1] *Standards and Standardization*, Chap. VII.

[2] See "Industrial Standardization," *Proc. I. Mech. E.*, June, 1933, p. 737; also "Standardisation in Canada," by W. R. McCaffrey, *Engineering Journal*, October, 1944.

ferences have been held for the purpose of promoting general standards.

Once the range to be covered by the proposed standard has been decided, a system of preferred numbers is frequently used to determine successive sizes. These are usually in geometrical progression, giving equal ratios between the sizes. Thus, if five sizes of motor are required to bridge the span between 10 and 100 horse-power, there will be a 60 per cent increase from one size to the next. The standard sizes will then be 10, 16, 25, 40, 63 and 100 horse-power, respectively. In a series of 10, the increase per step is 25 per cent.[1]

The process of industrial standardization is defined by Harriman as the "*evaluation of the several factors which will give the maximum feasible utility to materials, devices, processes or products. It also includes the establishment of allowable variations from specified measurements, liberal enough for economy of production and close enough for efficient functioning and effective interchangeability.*" Legal standards of quality or practice, are *minimum* requirements, from which unlimited variation is allowed in the preferred direction. The object of industrial standardization is the elimination of the waste of time, material, and labour involved in the production of numerous types, qualities, and sizes of articles for the same purpose.

Apart from the standardization of units of mass, length, time, etc., which are necessary for purposes of measurement, industrial standards are of three kinds, namely, standards of quality, practice, and performance.

(*a*) STANDARDS OF QUALITY. These consist of qualitative and quantitative descriptions of the material to be supplied or work to be done. The object of a *specification* is to define the characteristics of the article in such a way that when received it will be suitable for the purpose intended, without being unnecessarily expensive. Uniformity and reliability are important qualities, not only from the standpoint of safety, but also from that of economy in the subsequent manufacturing operations.

The limitations of the specification will vary according to the nature of the service for which the article is intended. When the specification is unnecessarily elaborate or rigid, the supplier frequently raises the price to protect himself against loss due to the possible rejection of some of the material supplied. Alternatively, constant demands for concessions are likely to be made after the

[1] *Heating Piping and Air Conditioning*, October, 1940.

work is in hand, at a time when cancellation of the order is impracticable. There are two main classes of specification, therefore, namely, those in which the predominant requirement is *safety* (e.g. aircraft work) and those in which the limiting conditions are those of manufacture and *economy*. With this proviso, the following schedule may be used when drawing up specifications for materials, and any or all of them may be included according to the judgment of the purchaser—

1. Class of material from which the articles are to be made, and, if necessary, name of firm or firms supplying that material.
2. Method of manufacture in more or less detail, noting any special requirements.
3. Dimensions and limits of accuracy.
4. Faults to be avoided in material and general quality required.
5. Chemical composition of material with limits if necessary.
6. Mechanical tests required and condition of test pieces (whether machined, normalized, heat-treated, etc.) when tested.
7. Form and sizes of test pieces, with limits.
8. Selection of test pieces, including proportion of tests taken, procedure of selection, and method of marking and numbering test pieces.
9. Method of inspection, by whom carried out, and when.
10. Specification of heat treatment, if required.
11. Return of material previously rejected by inspector, and procedure to be adopted.
12. Provision for independent tests in case of disagreement between supplier and purchaser.
13. Arrangements with reference to the proportion of the cost of preparing test pieces and testing to be borne by supplier and purchaser.
14. Method of marking or painting accepted and rejected material, and by whom this is to be done.
15. Stipulations with reference to the repair or patching of faulty pieces and procedure to be adopted.
16. Procedure for rough machining, pickling, sand blasting, or cleaning articles before leaving supplier's works so that defects may be observable.
17. Method of protecting articles from corrosion or damage during storage or transport, and the degree of such protection to be provided by supplier.

By the use of such specifications the variety of materials offered will be reduced, quotations from all suppliers will be comparable, production will be stabilized, and better deliveries obtained. In some cases, where the required quality is difficult to specify, comparison with samples is used, but this should only be resorted to where standards of measurement cannot be used.[1]

[1] "Materials Standardization," *Mechanical Engineering*, April, 1944, p. 259.

Such cases are becoming more and more rare, as even colours can now be matched by means of the photo-electric spectrometer, which analyses either reflected or transmitted light.[1] Jones[2] states that scientific specifications cannot be used when—

(1) The goods pass through a produce exchange that does its own grading.

(2) Raw materials originate with a number of small producers who are not controlled.

(3) Materials pass through the hands of a number of traders so that the original source is not accessible.

(4) Materials are controlled by a secret process.

(*b*) STANDARDS OF PRACTICE. These refer generally to safety codes which have been adopted by national or local governments, to embody the best practice with a minimum of hazard or inconvenience. Such codes or regulations as those governing the supply of electricity to buildings with a minimum of fire risk, the storage of light oils, braking and lighting regulations for automobiles, are included under this heading. Uniformity of practice is also stimulated by the existence of such standards, and public confidence is inspired in the manufacturers who use them. Conformity with such standards is usually indicated by a seal or stamp of approval.

(*c*) STANDARDS OF PERFORMANCE. These refer to the efficiency, economy, accuracy, or durability of the mechanism, and in this case the method of procedure must be laid down in considerable detail, as in the test codes of the Institution of Civil Engineers, the American Society for Testing Materials, and the American Society of Mechanical Engineers. The value of such comparisons depends not only upon the accuracy of the instruments used, but also upon the manner in which they are applied, and in many cases upon the position in which they are placed. The measurement of the flow of liquids and gases, for example, is very susceptible to these conditions, and wrong conclusions may be arrived at if these points are not carefully observed. In some instances, as in sampling fuels, wet steam or gases, it is impossible in practice to know whether the true figures have been obtained, but, by adherence to a standard method, inevitable errors are reduced to a minimum, and comparable results are obtained.

[1] *Manufacturing and Industrial Engineering*, June, 1936, and General Electric Company Bulletin G.E.A.—1298.

[2] *The Administration of Industrial Enterprises*, by Edward D. Jones.

The Application of Standardization.

The extent to which standardization has been applied in the United States is described by Lansburgh,[1] who gives examples which indicate an elimination of variety, varying from 22 to 98 per cent in different industries.[2] This has been due very largely to co-operation between the various companies operating in each industry, and to an increasing recognition of the fact that a diversity of output involves high production costs and increased selling prices. Thus, the standardization of material, processes, tools, and designs is advantageous both to producer and consumer. Other advantages are a reduction in the quantity and value of the stock that must be carried, more prompt deliveries of both raw material and finished products, ready availability of spare parts, and (probably) a better quality of output. The chief disadvantages are due to the difficulty of making improvements or changes in standardized products. Once a standard has been fixed and large numbers of jigs, tools, gauges, and other facilities for manufacture have been provided, it is a very expensive matter to make alterations, even though the change in itself would be an improvement. As an illustration the proposed adoption of the metric system of weights and measures may be cited. The theoretical advantages of such an international system are generally admitted, and in scientific work the change has been largely accomplished. For general use, however, the introduction of such a system would involve not only the duplication of our existing system of weights and measures (for repairs, renewals, etc., would still be required on old machinery), but a change in the mental processes of the people. The latter are now accustomed to think in terms of pounds, feet, etc., and if the new system were adopted, they would have to convert the new units back to the old ones before they could use them. This process is familiar to those who leave their native lands to live in foreign countries. For some time the units of money in the country of his adoption convey no idea of value to the newcomer.

This illustration indicates the kind of difficulty that is encountered in changing an accepted standard which has been woven into the fabric of industry. It is evident, therefore, that standardization should not be undertaken prematurely. Industries that are in the plastic stage should not be forced into

[1] *Industrial Management*, 1928, pp. 188–191.

[2] See also Jones (loc. cit.), pp. 307–310, "Simplification of Assortments" and "Report on Industrial Conditions in Canada and the United States," Appendix III. H.M. Stationery Office, 1927.

standard moulds until they are ready for them, as otherwise their natural development will be impeded rather than promoted.

Inflexibility, due to standardization of procedure, is illustrated by the following examples. A transformer, worth about $12.00, was included in an electrical apparatus for some years after it became unnecessary, because the cost of making the change was about $3600.00.

A special loudspeaker was required for a particular industrial application, and the total cost of producing it was about $40.00. The extra clerical and other work involved in putting through a special order, however, was $500.00, so that the price quoted was $540.00.

International co-operation in standardization is illustrated by a series of conferences held in New York (1943), London (1944), and Canada (1945) to eliminate the difficulties arising from the use of the Sellers screw thread in America and the Whitworth thread in Britain.

Sir Joseph Whitworth, when offering the first standard in 1841, stated the case as follows—

> Great inconvenience is found to arise from the variety of threads adopted by different manufacturers. The general provision for repairs is rendered at once expensive and imperfect. The difficulty of ascertaining the exact pitch of a particular thread, especially when it is not a sub-multiple of the common inch measure, occasions extreme embarrassment. As yet there is no recognized standard. This will not be a matter of great surprise, when it is considered that any standard must be to a great extent arbitrary.

The inconveniences and dangers of lack of standardization were also indicated by the British Information Services—[1]

> The resulting disparity between British and American standards has caused endless inconvenience, confusion, and expense. It was a hardship to the Allied Armies in World War I, and although in succeeding years efforts were made to work out a common standard no results had been achieved when World War II broke out. Difficulties arising from this cause were encountered when Britain, France, and other countries placed large orders in the United States and required the Whitworth thread. The situation was aggravated when large Lend-lease orders were placed.
>
> When the United States entered the war, the problem reached very serious proportions. For instance, a command might be using 50-calibre machine guns, some made in Britain and some in the United States. In appearance they would be identical, but their screw threads would be different, and so their parts would not be interchangeable.

[1] *Labour and Industry in Britain*, Vol. III, No. 8, August, 1945.

This meant that in every war theatre duplicate stocks of replacements had to be kept at the repair depots.

The direct cost to American manufacturers for extra taps, dies, and gauges alone is estimated to have been $100,000,000. In addition, time was lost on army orders by the change—army ordnance reporting that it took three times as long to produce goods with Whitworth thread.

As a result of these conferences a tentative standard was adopted, combining the advantages of the Sellers and Whitworth threads and, by the general adoption of this standard, it is expected that the situation will be improved materially.

The Canadian Standards Association[1] indicates the savings obtainable through simplification and standardization by the following examples—

1. *Simplification of Design of Pulley Bracket and incorporation of a self-aligning pulley in place of a rigid type*—

Old Design:	Material 1.75 lbs.	Time 25.89 man hrs.	Cost $37.55
New Design:	" .86 "	" .80 " "	" 2.43
Unit Saving:	" .89 "	" 25.09 " "	" $35.12

2. *Substitution of Casting for Sheet Metal Oil Cooler Support Bracket*—

Old Design:	Time 4.25 man hrs.	Cost $6.55
New Design:	" .70 " "	" 2.95
Unit Saving:	" 3.55 " "	" $3.60

3. *Substitution of Plywood for Corrosion Resistant Steel Locker Box*—

Steel Box:	Weight 10.5 lbs.	Time 4.12 man hrs.	Cost $13.45
Plywood Box:	" 4.4 "	" 3.00 " "	" 7.40
Unit Saving:	" 6.1 "	" 1.12 " "	" $6.05

4. *Substitution of 17 ST Rivets driven in the age-hardened condition for 17 ST Rivets driven after quenching*—

Resulting Factors in Savings	*Estimated Daily Savings*	
By less wastage of rivets	80 lbs. rivets at $2.00 per lb.	$160.00
By less reheat-treatment	400 lbs. rivets at $.03 per lb.	12.00
By less handling	75 men at $.50 per hr. at 9 hrs. per day	338.00
By elimination of ice boxes (i.e. of ice)	150 lbs. dry ice at 34.06c per lb.	52.00
By less material due to shorter rivets	5% x 700 lbs. at $2.00 per lb.	70.00
By fewer delays for rivetters	3 man hrs. per rivet team x 625 teams x $.60 per hr.	1,125.00
	Total	$1,757.00

[1]C.S.A. Bulletin, March 31, 1944.

Estimated cost increases due to
higher rejections, etc.......Cost per day................ $90.00
Net saving per day..........$1,667.00
Annual saving........305 x $1,667.00 = $509,000.00

Standardization and its natural consequence, the subdivision of labour into highly-specialized groups, have been objected to on account of the increasing monotony of the work and the consequent degradation of the worker when the process is devoid of variety, and requires little or no skill. There is probably some reason in this, but it is unquestionable that conditions of working have been improved enormously, hours have been shortened, and the possibility of a man improving his status has been greatly increased by the use of this system. The type of worker who suffers most under this monotony has a better chance of rising to the administrative ranks than he had before, because markets have been increased to such an extent that there has been a corresponding increase in the size of industry, and the number of executive positions has increased in still greater proportion. In recent years this monotony has been relieved to some extent by the use of suitable musical recordings played at intervals during the working periods.[1]

In days of depression the adoption of mass production has been blamed for all the ills of the world, and politicians and administrators have tried to put the clock back by prohibiting the use of machinery for certain operations. Excavation contracts made by municipal and other authorities sometimes contain the stipulation that steam shovels should not be used, so that hand shovels and more men may be employed. As one observer said, "Why not employ still more men and let them use teaspoons " This attitude is not restricted to the post-industrial revolution period as apparently it existed in Roman times (A.D. 14–96).

Some labour saving devices were rejected because they might have caused technological unemployment, and the purchasing power of the people was too low to stimulate and support mechanical production.[2]

[1] *Mechanical Engineering*, January, 1943, p. 31.
[2] *Caesar and Christ*, Will Durant, p. 323. (Simon & Schuster)

CHAPTER III

THE PRINCIPLES OF MANAGEMENT

Management may be defined generally as "the science or art of reaching a given end with the utmost economy of means." This definition is by no means specific, but it indicates the objective. Although the term "scientific management" has been very much to the fore in recent years, it is really only scientific in so far as the handling of inanimate *things* is concerned.

Materials or things can be handled scientifically because their properties and uses can be determined within close limits, their positions or movements are controllable and predictable, they can be replaced at slight cost and their form can be modified at will. The handling of *men*, on the other hand, is more of an art than a science, and usually can only be learned by experience. The application of logical principles to the solution of labour problems is frequently unsuccessful, because men are often illogical and are swayed by prejudice rather than by reason.

It is possible, however, to lay down some broad, general principles in this connection, and these are exemplified by the laws of leadership, exceptions and responsibility.[1]

The law of leadership. Wise leadership is more essential to successful operation than extensive organization or perfect equipment.

The law of exceptions.[2] *Managerial efficiency is greatly increased by concentrating managerial attention solely upon those executive matters which are variations from routine, plan, or standard.*

The law of responsibility. Responsibility for the execution of work must be accompanied by the authority to control and direct the means for doing the work.

The first of these laws indicates the relative importance of the individual, as distinct from the mechanism. In former years, it was considered that the best qualities for successful management were that combination of prudence and cunning, which obtained the maximum amount of work from the men, while depriving them of the whole or the greater part of the benefits that they should have derived therefrom. In these days a feeling of trust

[1] *Laws of Manufacturing Management*, Alford; and "The Unwritten Laws of Engineering," W. J. King, *Mechanical Engineering*, May, 1944.

[2] See also "Management by Exception," Chester B. Lord, *Trans. A.S.M.E.*, 1931.

is essential, if the best results are to be obtained. Without it, the men will be suspicious of every move and will act accordingly, but if they have found by experience that the manager treats them with fairness, they will do their best for him. Naturally, this fair dealing is not the only criterion, but it is probably the most important. The men who are worth while are willing to be *led*, but will not be *driven*.

The second law indicates that good management does not consist of rummaging into every detail of the business. This work should be left to responsible subordinates. If they are incompetent, or cannot be trusted to do the job properly, they should be replaced. When the manager's mind is filled with and his time taken up by a lot of detail work, he is unable to give sufficient attention to those larger questions of policy and coordination that are his primary business. A desk littered with reports, letters, and other documents is no indication of efficiency, but rather the reverse. Such documents and summaries as do reach the manager, should be comparative in form, so that he will form a true mental picture of what is happening.

The third law is really a corollary of the second and indicates that it is useless to saddle a man with responsibility without, at the same time, investing him with the necessary authority to carry out that responsibility. Too many managers are afraid to delegate authority to others, but such a procedure is necessary if good results are to be obtained.

While experience or *qualitative* knowledge is required for the management of *men*, it is necessary to have *quantitative* knowledge for the handling of *things*. The collection and the application of data, therefore, form an important part of scientific management, and this process is facilitated by the use of reports or graphs, which express the information gained and its meaning in forms that are easily digested.

The first systematic study of the principles of management was made by Dr. F. W. Taylor. He observed the difficulties of evaluating a day's work by previous performance and, by dividing each job into its elemental components, improving the conditions of work, selecting his men and training them to do particular jobs, he effected considerable economies and inaugurated a new conception of management.

The principles enumerated by Taylor were—

1. *There must be a scientific basis for each element of a man's work to replace the old rule-of-thumb methods.*

2. *The best worker must be selected for each task and then trained and developed for that task, instead of being left to teach himself.*

3. *Co-operation should be developed between management and men, to carry on the business in accordance with the principles of the developed science.*

4. *There must be a fair division of work between management and men, the former taking the responsibility and doing the necessary planning and thinking.*

The application of these principles led, among other things, to the development of time study, functional foremanship, the differential piece-work system, high-speed tool steel and many other improvements, which have proved to be of considerable value to industry.[1] After Taylor's retirement, a number of other men followed in his footsteps and, while several of them were capable and did good work, there were many others who understood very imperfectly the new principles that they were attempting to apply. As a consequence of numerous failures, the term "efficiency expert" became very unpopular, and Taylor's work was unjustly discredited in many quarters. The fault was not in the principles themselves, but in the manner of their application.

Gradually this came to be understood and, at the present time, specialized service of this kind is quite common, either by the use of departments within the organization, or by employing management consultants. The latter can often do good service by observing the existing organization with an unprejudiced eye, but in many cases their work is nullified by unfamiliarity with the special problems of the particular factory under investigation, or by the desire of the management, expressed or implied, to obtain economies or results in an impossibly short time.

Management has the following responsibilities to the owners, workers and public—

1. To THE STOCKHOLDERS. To give regular and reasonable returns on their investment without causing injury to workers, customers or the general public, and to present accurate reports at reasonable intervals.

2. To THEIR OWN EMPLOYEES. To give fair pay for a fair day's work, equitable treatment and opportunity for education and advancement. To provide steady work with safe and healthy working conditions. To recognize and reward individual merit.

[1]Taylor's published works include *Shop Management*, 1903, *The Principles of Scientific Management*, 1911, *The Art of Cutting Metals*, 1906.

3. To Suppliers' Employees. To pay fair prices, so that workers may not be exposed to "sweating" conditions. As far as possible to provide a steady and continuous demand and reasonable delivery schedules.

4. To Customers. To invest in goodwill by giving good values at low prices. To stay in business, thus ensuring continuity in the supply of goods and services.

5. To the General Public. To avoid pollution of air and water and other nuisances, such as unnecessary noises, odours or vibrations. To respect its responsibility to the community and carry its fair share of the general cost burden.[1]

The threefold duties of management are—

(a) *To establish a policy.*

(b) *To plan an organization for carrying out that policy.*

(c) *To operate the enterprise through that organization.*

The establishment of a policy includes decisions as to the particular types, quantities and sizes of articles to be produced. This depends, to some extent, on the kind of market which is to be supplied. Luxury production, as in the case of Rolls-Royce cars, is devised for a limited but fastidious market, whereas Ford cars supply a much larger, but less exacting, market. These, and similar questions, are usually decided by the board of directors.

The operation of the enterprise has three principal objects, namely, a high standard of quality in the finished goods, rapid manufacture, and low cost of production. These may be summarized as *good, rapid,* and *economical* work.

The standard of quality is necessarily relative, but, once decided upon, some system of inspection must be devised to ensure both the realization and maintenance of that standard.

Rapid manufacture depends partly upon continuity of supply. This involves the buying, the handling, and the transport of materials, and the system of following them through the manufacturing processes. It also depends upon the facilities available for converting the material into the desired form in the shortest possible time. Such facilities include high-speed tools, powerful and automatic machinery, efficient drives, jigs, fixtures, and other similar devices.

Economical work depends on the factors given in the previous paragraph because, if the standard of quality is maintained, rapid production gives low costs. Rapidity, however, is not the only essential. Forethought in design can save considerable

[1] *Mechanical Engineering*, August, 1938, p. 613.

expenditure in the shops, as it is easier to alter a drawing than it is to make the same change in a piece of metal.

Another important factor is the system of payment adopted. This should be so devised that the reward is proportional to the amount of *good* work done, but there are difficulties in applying this principle, as will be seen in a subsequent chapter. Taylor showed that it is sometimes economical to increase the rate of pay of a fast worker, in proportion to the amount of time saved. In any case, workers who are dissatisfied with the conditions of payment, will not produce the amount of work that they are capable of doing, and so the work will not be performed economically. A smooth-running organization, with neither an excess nor a deficiency of executives, and one in which there is hearty co-operation between management and men, will also assist materially in lowering production costs. Friction has the same effect both on mechanism and staff—it generates heat and reduces efficiency.

CHAPTER IV

ORGANIZATION

General.

The increasing size, or aggregation of industrial units, brought with it many advantages, some of which are tabulated in Chapter I; but large units of all kinds necessarily have many problems which are not met with in smaller and simpler plants. One of these problems is that of administration, which becomes less personal as the business grows in size. The work that was formerly done by individuals, becomes sufficiently important and voluminous to occupy the attention of departments or, in some cases, subsidiary factories. The manager of a small business keeps personally in touch with his men, and can make allowance for their individual characteristics and peculiarities, thus avoiding some internal friction. The inter-relationship of *groups* of men, however, cannot be handled with the same facility, and the division of labour into highly-specialized classes increases the difficulty of administration and creates a need for suitable co-ordinating influences. The kind of organization used, therefore, will depend primarily on the size and complexity of the business, and, to some extent, on the ability and personal characteristics of the available staff.

The term "organization" is used loosely, in practice, to indicate a number of different things, but in this chapter it refers to the *arrangement* or *structure* of the enterprise. In this sense it fulfils in industry the same purpose as the skeleton does in a man: it is the framework upon which the remainder of the edifice is erected. The object of organization, therefore, is to define the scope and duties of each department, or of each man, in such a way that responsibility is definitely allocated and the authority and limits of the various executives are implied. It is sometimes unwise, however, to express limits too clearly, as this may smother initiative and reduce interest in the business, and, in addition, may make the organization less flexible, by hindering necessary changes and re-arrangements.

Organization may be defined as "the arrangement of the work of individuals and groups, and the provision of the facilities necessary for doing that work, in such a way that the best, most efficient and economical results will be obtained."

This definition stresses the fact that good organization provides the *best* arrangement, and that is not necessarily the most *elaborate*. In the years that followed the "scientific management" boom, many a promising and ambitious firm was organized to death, being strangled by the coils of its own red tape. Organization is worth only what it saves, and, however scientific and logical in principle a proposed arrangement may be, the change should not be made unless it can be clearly demonstrated that economies in operation will result therefrom. In many cases, the immediate consequence is an increase in the overhead costs.

When an organization is planned, it should be sufficiently flexible to allow for changes and expansion. In business, as in many other things, a firm that is not advancing is usually retreating, and its probable increase in size must be allowed for. The necessity of training subordinates to fill vacancies as they arise, must also be borne in mind, not only in the interests of smooth operation, but also to give opportunities for advancement to young and able men. If these find by experience that they will be promoted as soon as vacancies occur, or when expansion takes place, they will be more contented and loyal to the firm and will give of their best, both mentally and physically, to procure advancement. A man who is dissatisfied with his prospects and is looking for a job elsewhere, is not only losing money for the firm by present inattention to his duties, but will cost them more when he leaves, by reason of the fact that somebody else will have to be trained to do his work.

Responsibility.

The allocation of responsibility is a very important feature; if there are gaps in the organization, trouble is bound to develop at those points, while if there is overlapping of duties, the situation will be almost as bad. When two men are jointly responsible for the same job, each will leave it to the other, and if anything goes wrong "passing the buck" becomes a favourite pastime. Responsibility is essentially *individual*, in spite of the fact that committees, boards, and commissions are frequently invested with it. In these cases, each group of men acts as a single unit, to which responsibility can be definitely brought home in case of necessity, and so they come within the same category as responsible individuals. The organization scheme, therefore, must provide definite lines of authority, so that each man will know

from whom he has to receive orders and which members of the staff must report to him. Usurpation of authority, and consequent internal difficulties, are not uncommon in some firms, but this is only possible where such lines of responsibility are not definitely fixed.

The number of subordinates that one executive can direct efficiently varies with the nature of the work and its importance. In shop work a foreman may have from ten to thirty men directly under him; for larger ratios, assistants are usually necessary. Higher executives, such as presidents or general managers, should not have more than five or six officers of the company directly responsible to them. When the complete scheme has been prepared and the duties and responsibilities of each position have been defined, a chart or diagram may be drawn to indicate their inter-relationship in a clear and convenient form. This provides a simple and definite way of indicating lines of authority.

One important factor in this connection is that of communication. Every executive should be able to reach his immediate superior in a minimum of time and with the least amount of effort. The installation of branch telephone systems within the works has facilitated internal communication to a great extent, but there are many occasions when personal interviews are necessary.

In one works the author had to walk a quarter of a mile to reach his superior, and then frequently had to wait half an hour before he was admitted to the office. This was a waste of time and money, some of which could have been avoided if the works had been properly laid out in the first place. The trouble is that many firms grew, in a haphazard manner, without any definite plans for expansion, and for that reason were inefficient in operation. As an example of the opposite kind, Fig. IV.1. shows the office arrangement of a prominent English machine tool firm. The managing director, general manager, and director of finance are near to one another and to the board room. Round the central hall are placed the offices of the principal executives, and round them again are the offices for which they are responsible. Thus, the directors of design are next to the Engineering and Design Department; the secretary and cashier are near to their respective offices, and the sales, shipping, and other executives are in close proximity to their departments.

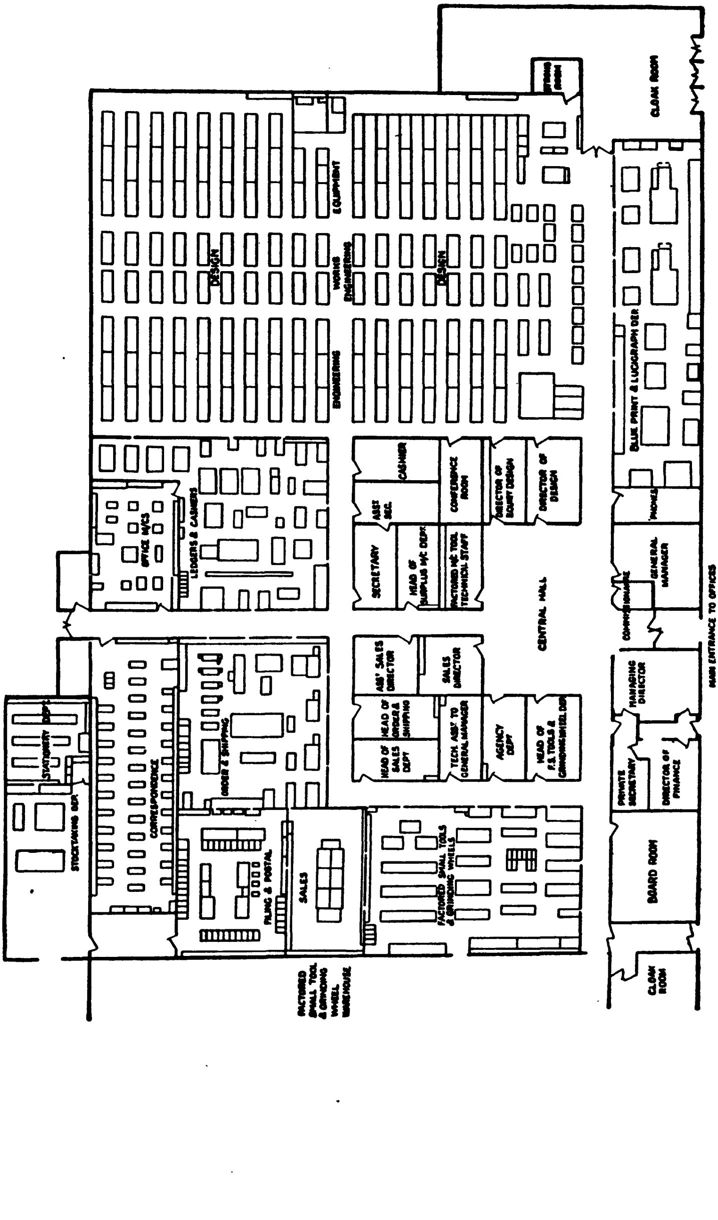


FIG. IV.1. LAY-OUT OF OFFICES

Records.

The establishment of an adequate system of records is essential to the success of any organization, but it is necessary also to make a systematic use of recorded experience. Records that are not used, or that are duplicates of other documents, should be discontinued, as they represent wasteful expenditure. It is important moreover that the recording system be easily understandable, so that the absence of a key man will not paralyse the whole system. Memory work should be reduced to a minimum, for the same reason.

Types of Industry.

The kind of organization that is most suitable for any business depends upon the nature of the industry, and particularly on the extent to which this industry is standardized. Kimball[1] divides manufacturing industries into *continuous* and *intermittent* types. The former are those in which there is a steady flow of material through the plant, raw material entering at one end, and finished products leaving at the other, as in a paper mill. Continuous processes may be *analytical*, where a complex material is split up into its component parts, so that each may be used to the best advantage. An example of this is a gasworks, where coal is analysed into gas, coke, tar, and commercial products, by a continuous process of heating and washing. Another form is the *synthetic* process, in which the finished product is built up from a number of small components. Mass production schemes, such as the fabrication of automobiles, are mostly of this type.

Intermittent processes are also of two kinds. In semi-continuous processes large numbers of components are made, and then are stored until required for assembling into finished products. The manufacture of cast-iron radiators is an example of this type. Large numbers of one particular size of steam radiator section are cast, machined, and put into the stores. The patterns in the moulding machines are then changed to some other size, and no more of the first kind are made until the stock of castings becomes low. In the meantime, radiators of various sizes are assembled from the stock of sections in the stores.

Completely intermittent industries are those in which the work proceeds to special order, or contract. Large engines, turbines, ships, and bridges are built in this way. Although

[1] *Principles of Industrial Organization.*

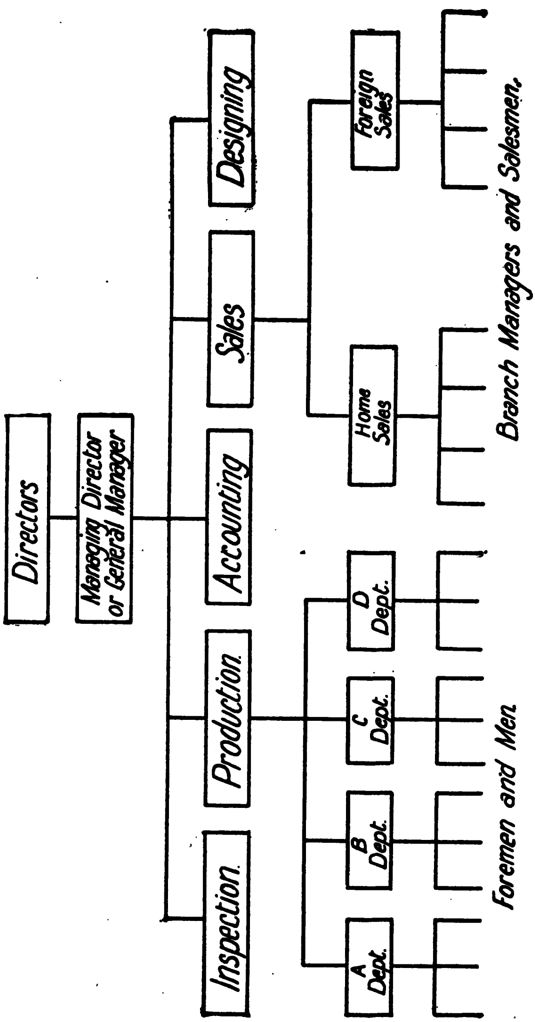


FIG. IV.2. DIAGRAM OF MILITARY OR LINE TYPE OF ORGANIZATION
The Production and Sales Departments only are partly shown.
Inspection, Accounting, and Design Departments are developed in a similar manner.

some components may be kept in stock, it is necessary to make the large castings, forgings, or trusses specially for each job. In these cases, the amount of standardization of dimensions and processes is less than in those described previously, and the organization must be arranged to suit this condition. It is easier to delegate responsibility in a fully standardized business than in one where the work is varied.

Forms of Organization.

1. MILITARY OR LINE TYPE. This is the oldest kind of organization, being based on the division of labour into a number of sections or shops, each controlled by a foreman, or chargehand. The foremen, in their turn, are responsible to the works manager or superintendent who, with his colleagues of equal rank, reports to the general manager. This arrangement is indicated by the diagram (Fig. IV.2.), which resembles an inverted tree, where the trunk divides into branches, and these into smaller branches and twigs. The horizontal lines on this chart indicate equality of rank, and their separation vertically illustrates their independence of each other. This arrangement makes it possible to grade the staff, in proportion to the amount of responsibility borne. Thus, "A" staff might consist of superintendents, "B" of assistant superintendents, "C" of foremen, and so on. This is a convenience when standardizing salary scales and staff bonuses. Vertical lines show the manner in which authority and responsibility are distributed; lines of instruction flow downward, while reports move in the opposite direction. The military type (now a misnomer) depends, to a large extent, rather on segregation than on sequence of processes. The machine shop, under this system, has one section devoted to lathes, another to milling machines, others to drills, shapers, etc. This means that the work is transported from section to section in a roundabout way, according to the order in which the various processes have to be performed. While this system has the advantages of simplicity, flexibility, and definiteness, it suffers from the disadvantages of duplication of effort, high costs, conflicting policies, and lack of co-ordination.

2. FUNCTIONAL TYPE. One of the principal difficulties in applying the military type lies in the training and employment of foremen or supervisors. The importance of this post and the nature of the troubles experienced, is indicated in the following extract from an editorial in *Engineering*[1]—

[1]18th May, 1923.

The fact that a foreman has to deal chiefly with the difficulties and capabilities of workmen points to the choice of a superior man of that class. The promotion of a good workman has the great advantage that the foreman then has an expert knowledge of the trade carried on by his men, and is thus a good judge of their ability and industry, and, moreover, being of the same social class and of the same upbringing and training, he can enter with real sympathy into the difficulties of the man and, by timely encouragement or admonition, can maintain a corporate spirit in the shop and avoid too frequent changes of personnel. But though these advantages are very great, and usually result in the choice of a superior workman to fill such posts, some of the essentials for really satisfactory work are missing.

The training of the British artisan is thorough, but it is, unfortunately, narrow. *The breadth of trade knowledge desirable in an officer of an important concern is seldom acquired, and still less the requisite general knowledge.* The absence of these things is chiefly felt in the effect upon the *mentality of the foreman; for here the narrowness of training is reflected in narrowness of outlook and inflexibility.* Thus it usually happens that, where a management is progressive, their *programme of advance is continually being held up because the permeability of the foreman to ideas is too small; where they rely on the initiative of the foreman to develop his own ideas the result is generally nil.*

The choice of a foreman is extremely important, because of the immense power of that officer to affect the affairs of the works for better or for worse. Although the post is not one of very high rank, it *joins up the activities of the two great branches of a factory; the devising and directing, and the actual producing. It is on the effective co-operation of these two functions that success depends* and, consequently, the position of the foreman is a much more important one than appears to be generally admitted. If the foreman chosen is a strongly practical man and a good disciplinarian that is all to the good, but if he is of such a temperament that he opposes all innovations he will not be a success from the point of view of the management. Yet this is, too frequently, what happens. *The opposition of the foreman to new ideas originating from "above" is seldom open, but, nevertheless, it exists. The men soon discover this and act in concert to abet their foreman in resisting innovations against which they, too, are prejudiced.* The foreman may be got to acquiesce in the introduction of something new, but mere acquiescence is of comparatively little use. What is required is intelligence to perceive the new conception, and ability to introduce it into the department; for in all such matters the foreman is the only effective go-between for introducing the ideas of the management to the men. It is as though the workmen spoke one language and management another, the foreman being the necessary interpreter.

It follows, then, that the foreman must be capable of analysing *two differing types of expression* for, *not only must he introduce the ideas of the management to the shop, but he must interpret the objections of the shop to the management.* In many cases it happens that the management explains a proposal to the foreman; the foreman knows instinctively, from his lifelong connection with the shop, that the pro-

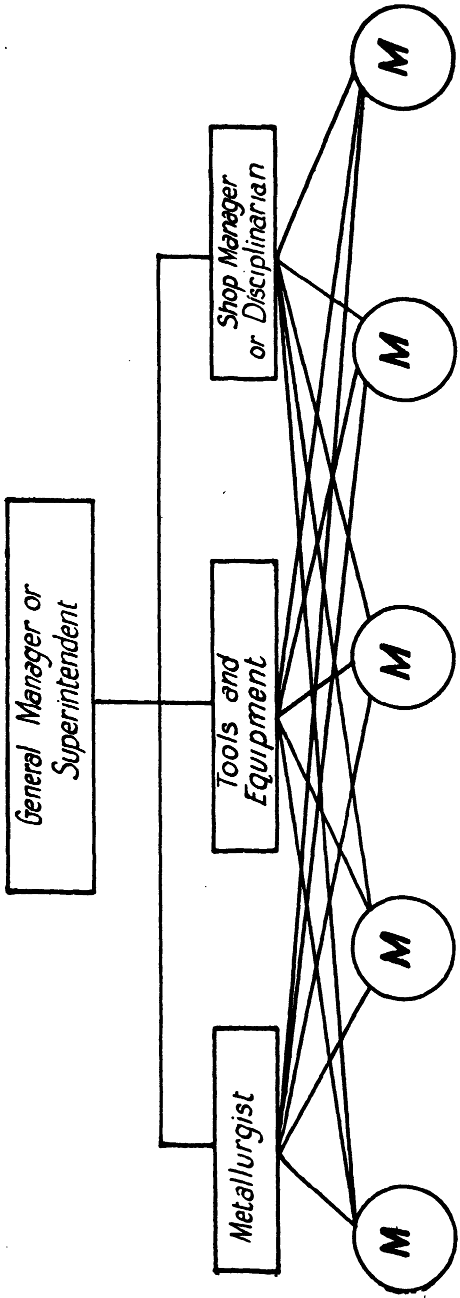


FIG. IV.3. DIAGRAM OF FUNCTIONAL TYPE OF ORGANIZATION
Each man receives instruction from three sources.

posal will not work; yet he cannot say why, and, consequently, offers a kind of grudging acceptance, which is of no use either to himself or to the management. What is required in this connection is a more analytical type of mind in the foreman. This, however, is seldom found in connection with the trade knowledge and powers of control also required for the post.

The foreman in the military organization has to estimate the cost of work, hire labour, allocate work and see that all machines are occupied, look after the progress of material, arrange machine and tool lay-outs, set time and piece rates, inspect the work, act as shop disciplinarian, and supervise everything relating to the shop. Taylor estimated that to do this job satisfactorily, a combination of no less than ten different qualities was required. Three of these could be obtained for labourers' wages, four commanded a higher price, five were hard to find, and more were almost impossible. Certain parts of the foreman's job were done well, and the rest were very badly performed, because it was impossible for any one man to be expert in all of the above-mentioned work.

The selection, training and functioning of foremen has received considerable attention during the past few years. The following observations are characteristic[1]—

(1) Care should be taken in the selection of potential foremen and in their preliminary training.

(2) The new foreman should be properly trained in the duties of his position.

(3) His responsibilities and authority must be clearly defined. Fairness and firmness must characterize his attitude to the personnel under his control.

(4) He must be made to realise that he is part of the management organization. The objectives, policies and procedures of the company must be clearly explained to him.

(5) He must have the support and encouragement of the higher management.

(6) As far as possible he should be consulted before major changes in policy are made, that will affect him.

(7) He must be kept informed of changes of policy or decisions that affect him.

(8) He must receive fair treatment from higher management and his contribution to the objective of the organization must be recognized.

[1]"The Foreman as Part of Management," by H. B. Coen, *Mechanical Engineering*, April, 1944.

The functional system, introduced by Taylor, is a logical extension of the division of labour, to cover departments, as well as men. If it pays to keep a man employed continuously on similar work in which he becomes expert, the same principle may reasonably be applied to his instruction. Thus, in the functional type (Fig. IV.3.), each superintendent or foreman is a specialist in his own field, and any workman may receive instruction from several expert sources, so that the directing intelligence is equalized for all phases of the work. In this system *planning* is separated from *performance*, and "functional foremanship increases in effectiveness as the work of the shop and of the individual operative increase in variety and complexity, and as the technical intelligence required exceeds the capacity of the worker."[1] The principal disadvantage of this system is the weakening of discipline that results from the substitution of several superior officers for one. The question of whether a man can serve two masters is discussed in detail by Lansburgh,[2] and illustrations are given to show that confusion need not necessarily result, if the scheme is properly applied. While this is doubtless true, the fact is that conflict of authority frequently does arise, and the successful application of the functional system depends almost entirely on the characteristics of the people who have to work together.

3. LINE AND STAFF TYPE. For the reasons given above, the functional system is seldom used alone in engineering works, but is grafted on to the military or line type, the combination being called the "line and staff type" of organization (Fig. IV.4.). Knoeppel[3] says that "the chief function of the staff is to *analyse* and point out the road to business efficiency. The task of *attaining* the ideals pointed out is the function of the line." In other words, the duty of the staff is to indicate ways and means, and that of the line is to get things done. Several writers have likened the staff and line functions to the organization of an army. The colonel commands his regiment and the captain his company, but specialized services for the whole army are provided by the engineers, medical and army service corps.[4]

The past decade has witnessed a decided tendency to return to the principle of one man control at any one point in the

[1] *Industrial Engineering and Management*, Anderson, p. 54.
[2] *Industrial Management*, p. 52.
[3] *Installing Efficiency Methods*, p. 58.
[4] See *Administration of Industrial Enterprises*, E. D. Jones.

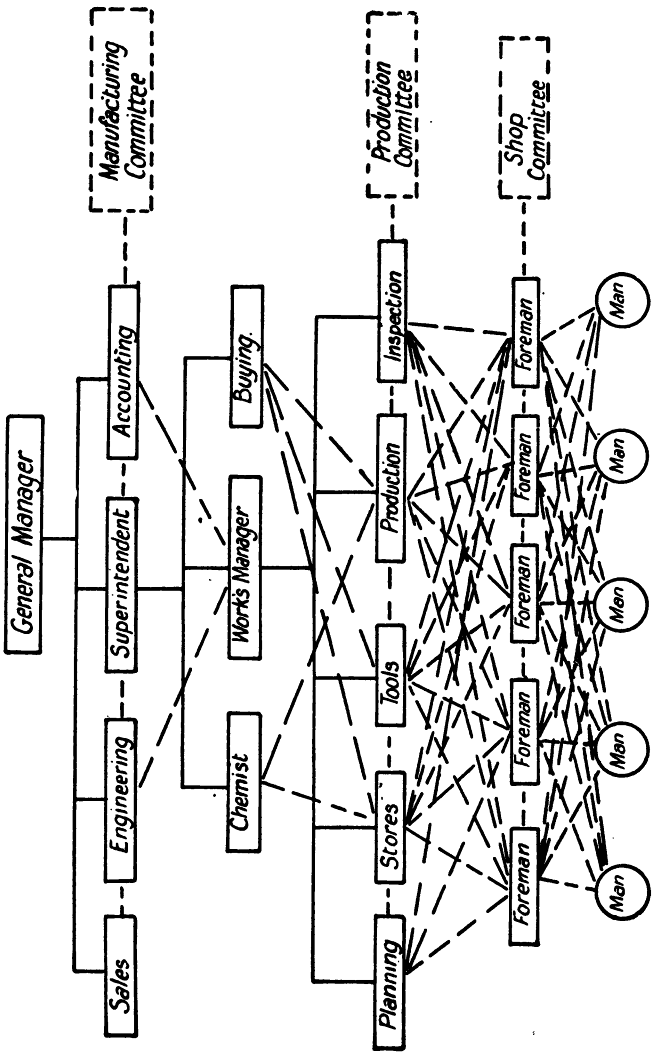


FIG. IV.4. DIAGRAM OF LINE AND STAFF TYPE OF ORGANIZATION

organization.[1] In the larger companies it is customary to have one official, usually the chairman of the board, who devotes his time to major matters of policy, public relations and long-time plans and programmes, free from the many demands of the daily running of the business. The actual operating is left to a chief executive (variously styled; e.g., president or executive vice-president) who deals with current administrative problems.

The "staff" may consist of a group of specialists, with no administrative or routine duties, who act in a co-ordinating capacity, carrying on broad constructive work and supervise their particular specialties. These staff officers have charge of no departments and have no regular duties except as delegated by the president or vice-president to whom they are advisers. They have no regular authority save by virtue of their knowledge and position. When their recommendations are to be translated into action they must persuade the line official concerned that such action is desirable, and all orders putting such action into effect are transmitted by and through line officials. The staff thus neither exercises authority over the line nor performs line work for an operating official.

Responsibility and authority follow the line type, so that the functional part of the system is largely advisory and is frequently applied by means of committees. These are used to suggest courses of action, and to give the considered advice of those best qualified to assist. This method works satisfactorily provided that the committees have no executive power or duties.

Committees may be *specific* or *general*. The former have definite duties to perform in advising the various departments along certain lines (e.g. tool committee), and are functional in their action. General committees are only partly functional and have no definite duties. The activities of these committees may be indicated by the following example. Each shop foreman has a small committee, meeting at regular intervals, to discuss problems and suggest improvements in that shop. The minutes of these committees are forwarded to a departmental committee of which the various foremen are members, and all of the important items are discussed there. The departmental managers, under the chairmanship of the general manager, form a manufacturing committee, to which go all important resolutions from the various departmental committees. In this way the whole of the committee system is focused on the general manager.

[1] "Defunctionalization of Industry," H. H. Farquhar, *Trans. A.S.M.E.*, April, 1943, p. 218.

There is some disagreement among management experts regarding the value of committees. An investigation[1] in the United States indicated that they serve a real function, without overlap in purpose or objective between committees properly established and regular staff departments. Whereas the latter are used to provide specialized and expert advice in particular fields, committees should be created only when it is desired to obtain the co-ordinated best judgment of a particular group. Committees are an effective device, (1) to co-ordinate activities, (2) to provide well considered recommendations on matters of company-wide concern, (3) to provide group judgment in lieu of individual judgment on such matters as salaries, appropriations or promotions. They are also an excellent training medium for the members composing them.

[1]"The Problems of Management," W. P. Fiske, *Mechanical Engineering*, July, 1942.

CHAPTER V

REPORTS

A report is a record of observations made, or of work done. It may refer either to achieved or expected results. Its object is to convey to the management a mental picture of existing conditions or of future tendencies. *Orders or directions* move down the organization, and must contain all the information necessary for carrying them out; they must be concise and complete. *Reports or returns* flow in the opposite direction, and refer to the fulfilment of the orders. They may be either *periodic* or *special*.

Periodic reports are those prepared at regular intervals (weekly or monthly) to convey to the management such information as the amount of stock or of raw material on hand, the quantity and condition of work in progress, the cost of production and other items necessary to show whether the required rate of production is being maintained, and whether it is costing more than it should. These facts are frequently embodied in monthly profit and loss statements, which enable a continuous check to be kept on manufacturing and selling operations. Other reports, relating either to the whole factory or to any department within it, will readily suggest themselves, but the object of all of them is to substitute definite and statistical information for the vague and general knowledge of the old type of executive.

Some managers, however, have a tendency to overdo this process, as follows: One day the manager requires certain information, which is not immediately forthcoming, and in a fit of irritation gives instructions that a periodic report is to be made on this subject, regardless of the fact that the same kind of information may not be required again for a considerable time. He forgets all about this order, but in the meantime his staff is kept busy compiling reports that are never used. Such periodic reports are a source of waste, and should be replaced by *special* reports which are made only when they are needed.

Written Reports.[1]

Departmental or statistical reports are usually given in the form of tabulated figures, and are sometimes accompanied by a

[1]See *Industrial Surveys and Reports*, Rautenstrauch, 1940.

written summary or by diagrams. In any case, the form of the report must be such as to indicate *comparative* results, because, unless the figures can be compared with some standard, they are meaningless. As an example, the case of a power plant may be cited. The fuel consumption is usually expressed in pounds of coal per kilowatt hour generated. This figure, however, conveys no idea of the efficiency of the plant or of the possibilities of improvement, unless previous results are available for the same plant, or contemporary figures for other plants of a similar size. If the comparison is unfavourable, it is necessary to analyse this figure into its component parts by means of a heat balance, to find out what part of the generating system is at fault.

Written reports should be concise, covering all essential points without wasting time or space on unnecessary details. Some special reports must be given at length so that a record may be kept of the study from which the conclusions were derived. In such instances, it is advisable to include a summary of the important facts and findings at the beginning or at the end of the report. The busy executive usually reads the summary and then refers to the body of the report for further information regarding some of the recommendations. Long reports should be divided into paragraphs, and sometimes indexed to facilitate this process. The report should be easy to read and understand, and for this reason long words and sentences should be avoided as much as possible. Good, clear English should be used, and, if the reports are for commercial men or for public bodies, technical terms should be used sparingly. An important point in such cases is to maintain a sense of proportion, so that important facts are given due emphasis and are not obscured by minor details.

Crawford[1] gives the following rules for engineering writing generally—

1. Have a worth-while subject and something to write.
2. State your purpose first and end with a conclusion.
3. Define your terms clearly and avoid ambiguity in their use.

Examples of such faulty usage are as follows—

In the East St. Louis *plant*, there is a high-octane gasoline *plant* and a dewaxing *plant*. The crude oil is heated in a large *heater unit*, piped to a cracking *unit* consisting of several Dubbs *units*.

[1] "On Engineering Writing," *Mechanical Engineering*, September, 1945, pp. 607–9.

Unit No. 1 in the Delray plant consists of a turbine *unit* and a boiler *unit.* Boiler water is prepared in a treating *unit,* and the control room is heated by *unit* heaters.

4. Use correct grammar.
5. Try to write in an attractive style.
6. Distinguish fact from opinion.
7. Use tabulation and indentation where clarity or legibility may be improved.
8. Be careful of punctuation.

The report should be made on paper of standard size with ample margins for filing purposes. The title should be chosen carefully to indicate the subject of the report for convenience in indexing. Statistics, tables or curves that are essential to the argument should be part of the main report, but if they are only required for reference they should be placed in an appendix.

Graphical Reports.

Written reports are statements of fact, but such records, even though they are expressed in comparative form, are frequently difficult to visualize or assimilate. Curves, or other graphical devices, employ symbols to illustrate the facts in a simple and convenient form, and also have the advantage of indicating *tendencies.* Graphical reports are inferior in accuracy to numerical statements, but are better for making comparisons.

The idea of using symbols in different forms to represent magnitudes is illustrated by Szepesi,[1] from whose paper Figs. V.1., 2., and 3. are reproduced. Each of these represents the fact

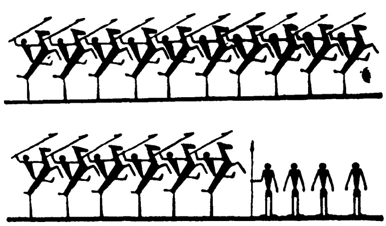


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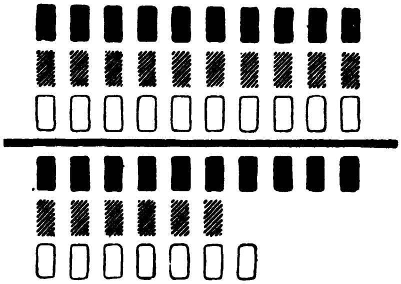
FIG. V.1. PICTORIAL FORM OF CHART
Required: 10 men, 10 spears, 10 horses.
Available: 10 men, 7 spears, 6 horses.

that ten men, ten horses, and ten spears are required for a hunt, and that ten men, six horses, and seven spears are available. Fig. V.1. gives the information in such a way that little or no

[1] "New Dynamic Device for Scheduling by the Gantt Chart Principle," *Trans. A.S.M.E.*, 4th February, 1929.

description is required. Fig. V.2. indicates numbers but needs a qualitative description of the different rectangles or blocks. Fig. V.3. requires also a quantitative description, or scale to supplement the diagram. These charts can be constructed for industrial conditions to indicate not only failure to realize the required standard of performance, but also the reason for such



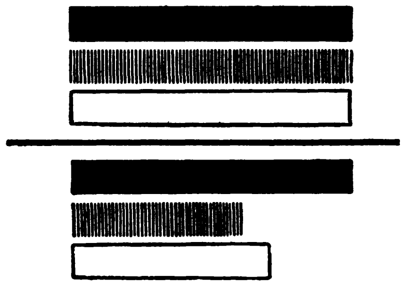


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FIG. V.2. SAME FACTS AS IN FIG. V.1. CONVEYED BY SYMBOLS

FIG. V.3. SAME FACTS AS IN FIGS. V.1. AND V.2., BUT DIFFERENTLY EXPRESSED

failures. When extended into curves, they also form a convenient method of comparing different phenomena, indicate similarities and differences, and suggest in what directions investigation is needed. In preparing such curves it is advisable not to use too many lines on one diagram, and to keep the lines distinct from each other. The scale of the diagram must also be chosen carefully, so that the actual extent of any variation is correctly indicated. For instance, the speed of a machine may actually be very steady, but by choosing an open scale for the curve it may appear to be fluctuating violently. Similarly, by choosing too close a scale, considerable variations may not be indicated by the form of the curve.

In some instances it is desirable to start the scale at the zero point so that variations from average figures may appear in their correct proportions.

Rates of change and other special curves involving large ranges of figures may be shown conveniently by using logarithmic scales for one or both of the ordinates.

The curves used in engineering practice are of two principal kinds—

1. Those drawn on a *time* base—usually *production* curves.

2. Those drawn on a *quantity* base—usually, but not invariably, *economy* curves.

An example of the former is the output curve or "Z" chart given in Fig. V.4. This shows the output month by month in line **WZ** which may be compared with the required output **ST** The required cumulative total is shown by the line **OX** and the actual cumulative total by **OY**. The line **PY** is the moving

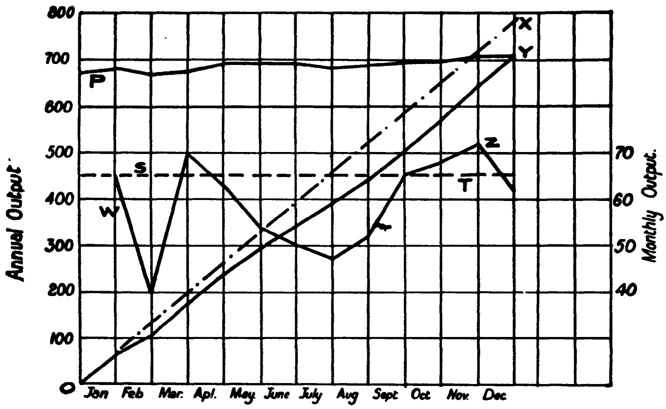
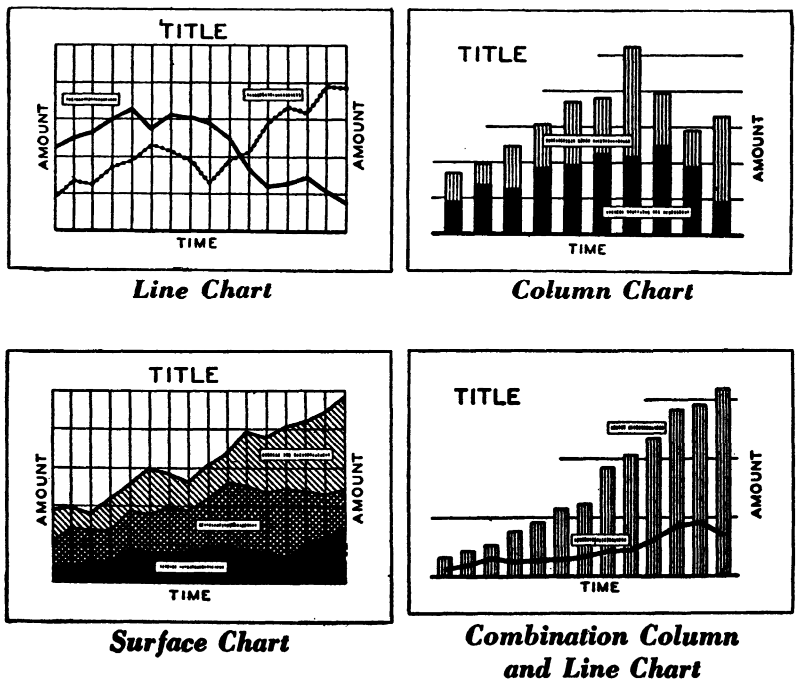


FIG. V.4. OUTPUT CURVES



Line Chart *Column Chart*

Surface Chart *Combination Column and Line Chart*

FIG. V.5. STANDARD TIME SERIES CHARTS

annual total, and is the total production for the previous twelve months, including the current month. The lines **WZ** and **ST** are plotted to a larger scale than the others for the sake of convenience. Charts of this kind should only be drawn in cases where they are necessary to supplement the tabulated figures, as the latter have to be compiled in any case, and the drawings are sometimes expensive in time and cost.

The American Standards Association has recommended standard forms for the presentation of "Time Series" charts, as shown in Fig. V.5., and has indicated the relative advantages and disadvantages of the different varieties of chart for various purposes.[1]

A different form of chart was devised by Gantt,[2] and this is frequently used for production and sales purposes. The progress form of this chart is shown in Fig. V.6., which indicates the degree of completion of six components at the end of 18th September. This date is shown by the arrow at the top of the diagram, which is moved forward from day to day. The angles represent the dates at which each job is due to begin, and the thick lines give the amount of work already done. Reasons for delay are indicated by symbols below the line.

The interpretation of the chart is as follows—

Job No. 5381 has eight operations, the first being due to commence on 3rd September. It should be completed on 24th September, and the sixth operation is due to start on 19th September. Five operations have been completed and the job is up to schedule. This is indicated by the fact that the thick line ends at the arrow.

Job No. 5462 is about to commence the ninth and last operation, but this was not due until 24th September, so that the job is five days ahead of programme.

Job No. 5463 is completed.

Job No. 5736 was supposed to be finished on 17th September, but is now six days behind, due to lack of tools for commencing the fifth operation.

Job No. 5479 is stopped at the third operation for repairs to the machine and is now nine days behind.

Job No. 6231 is three days late on account of shortage of labour for the fifth operation.

It is evident that a glance down this chart indicates immediately which jobs are delayed and the reasons for the delay in each case, so that the executives responsible can take prompt action. This chart can be kept up to date with little labour. It

[1]"Code of Preferred Practice for Graphic Presentation Time Series Charts," (*A.S.M.E.*).

[2]See *The Gantt Chart*, Wallace Clark.

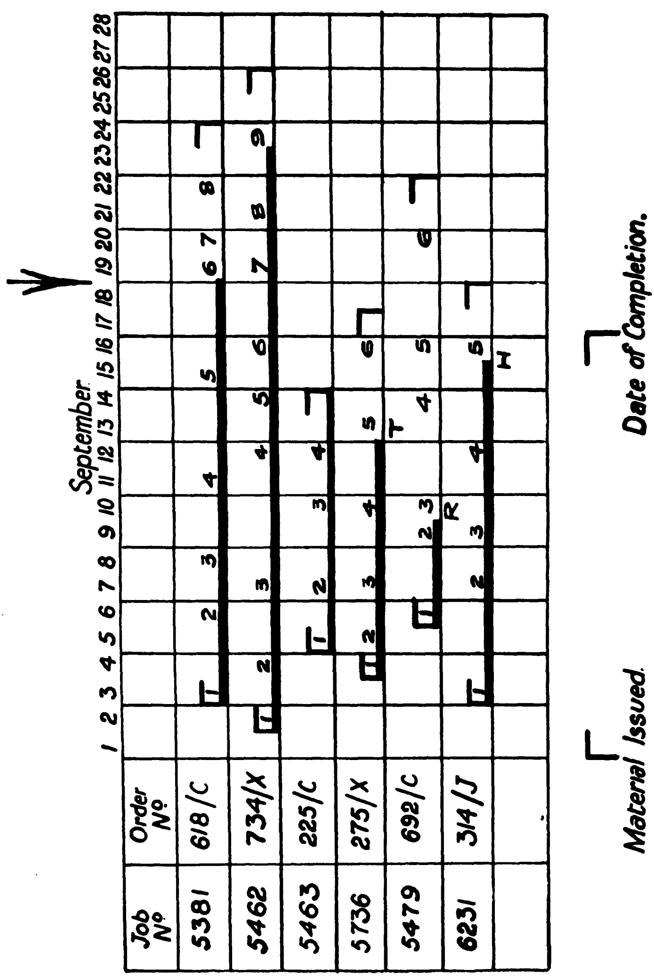
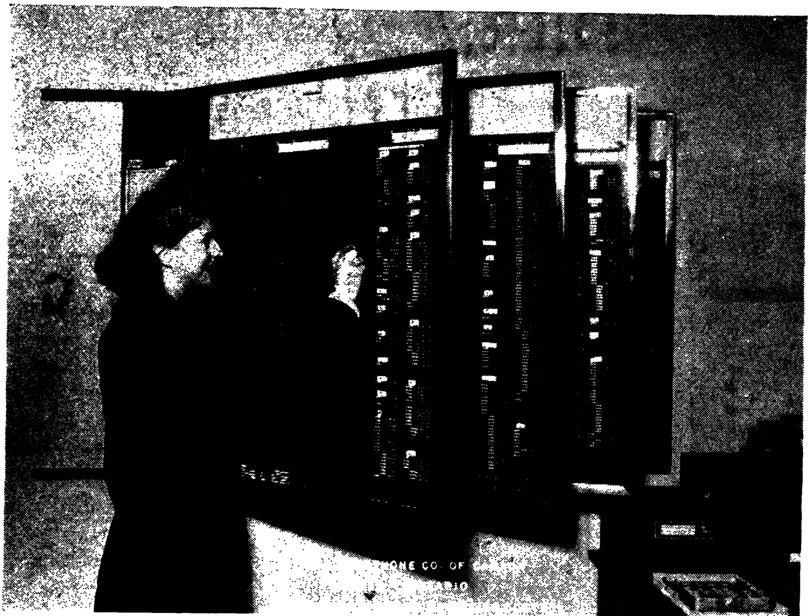


Fig. V.6. Gantt Progress Chart

is also suitable for showing the idle time of machines and the production of the various men. It has been used in a mechanical form (Fig. V.7.), which can be manually operated by means of strings and coloured pins.

The Produc-trol (Fig. V.7.) is one of the mechanical forms of chart that consists of a black board with horizontal white or



(*Courtesy of Seeley Systems Corp. Ltd., Toronto*)

FIG. V.7. MECHANICAL FORM OF CHART (Produc-trol)

coloured tapes and tape pegs. Vertical cords may be stretched from the top to the bottom of the board to indicate key dates or periods. This principle is similar to that of the Gantt chart but provides flexibility, as the horizontal and vertical cords may be moved from time to time, thus keeping all records up to date without drawing new charts. Suitably ruled forms are provided on the side of the board for identifying the order or process represented by each tape and peg.

Economy curves are illustrated by Figs. V.8. and V.9., which are plotted from tests on a steam engine. Fig. V.8. shows the manner in which the heat consumption of the engine rises as the load or brake horse power increases. It indicates that there is a no-load consumption of about 400 B.Th.U., and that as the load is applied, the heat consumed increases almost in

direct proportion. Also, that the effect of steam jacketing the cylinders is to give a considerable reduction in heat consumption. This is shown by the fact that the line marked **CJ** is well below the others. The same facts are shown in Fig. V.9. in a different way. In this case, the steam supplied *per unit of power* is plotted against the load on the engine, so that the poor economy of running at light loads is clearly indicated. The flatness of the

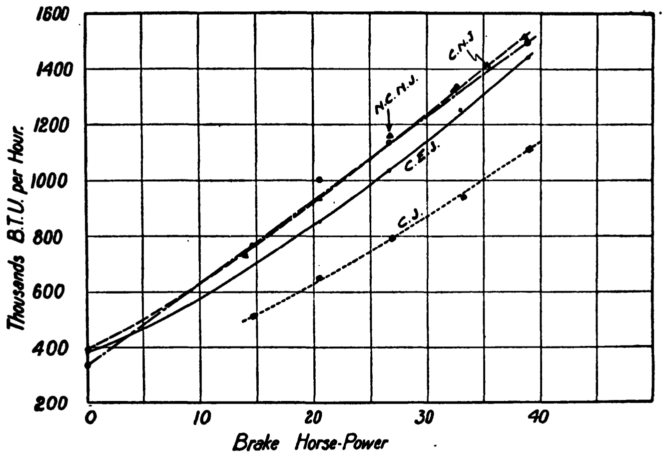


FIG. V.8. HEAT CONSUMPTION OF STEAM ENGINE

C. = Condensing. *J.* = Jacketed. *N.J.* = Non Jacketed.
N.C. = Non Condensing. *E.J.* = End Jackets only.

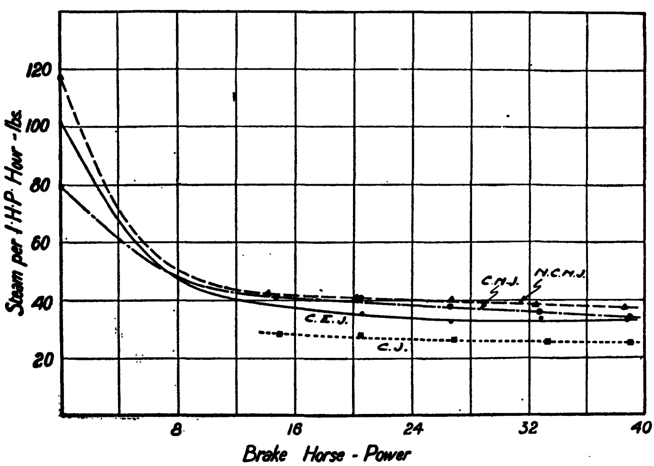


FIG. V.9. STEAM CONSUMPTION OF STEAM ENGINE

C. = Condensing. *J.* = Jacketed. *N.J.* = Non Jacketed.
N.C. = Non Condensing. *E. J.* = End Jackets only.

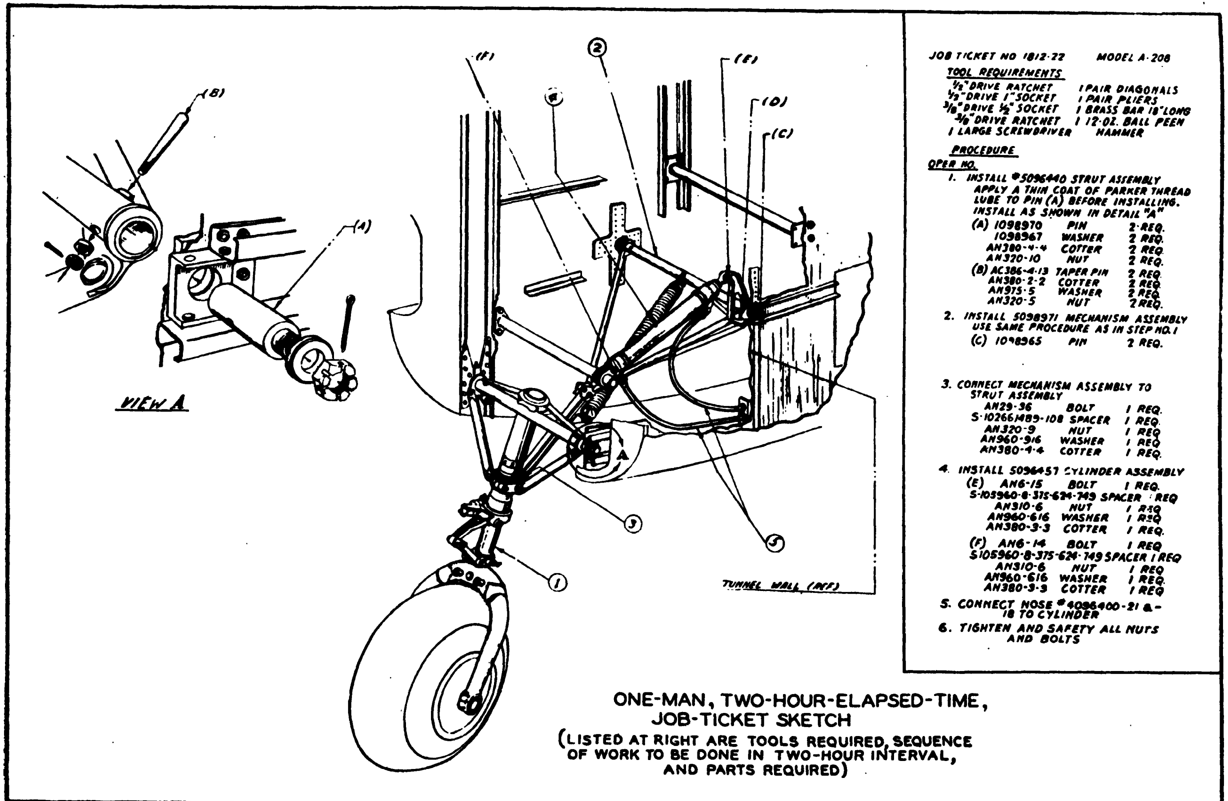
curve CJ indicates that the thermal efficiency is practically the same between 14 b.h.p. and 40 b.h.p. Many other instances might be given to show how the same facts may be presented in different ways for different purposes, but these examples are sufficient to illustrate the point.

CHAPTER VI

DESIGNING AND DRAFTING

Theoretically, all orders and instructions for work to be done should come from the manager, but practically many of these orders are too complicated to be given verbally, or in writing. It is necessary, therefore, to supplement or supersede them by diagrams, which illustrate the kind and quantity of work to be performed, and these are prepared in the drafting department or drawing office. The drawings issued by this department must give a description, in the most convenient and understandable form, of the work to be done. Thus, a drawing may be defined as "a series of instructions expressed by lines and figures." In the early days of engineering simple instructions were given in words. With the advent of standardization and mass production this process has again come into use in the form of *operation sheets*, which may contain no drawings at all. This has been made possible by the use of simple processes and standard machines and tools. These sheets give detailed instructions regarding the order in which the various manufacturing processes are to be performed, the limits of accuracy required, the machines and tools to be used, etc., but detailed drawings are still necessary to enable the operation sheets to be prepared. The only change is that, in this case, the operator does not *see* the drawings. During World War II, particularly in industries that employed a high percentage of unskilled labour, the practice of using pictorial illustrations in place of, or in addition to conventional drawings, received considerable impetus. An example from the aircraft industry is shown in Fig. VI.1. The designing and drafting department thus occupies an important intermediary position between the management and the works. Its duties are—

1. The calculation of quantities and strengths and the preparation of designs and specifications.
2. The preparation and checking of detailed or working drawings, and the issue of blueprints, or other replicas, to the shops.
3. The design and drawing of facilities for production (jigs, tools, and gauges), and the issue of working instructions.



(*Courtesy of* Mecnanical Engineering)

FIG. VI.1. PICTORIAL TYPE OF DRAWING. EXAMPLE FROM AIRCRAFT INDUSTRY

The third function is sometimes fulfilled by a separate office, or by the planning department, but in so far as it entails the use and issue of drawings, it may pertinently be considered at this stage.

Departmental Organization.

Large firms, specializing on a single type of product, almost invariably have a central drafting room, divided into sections corresponding to the various component parts of the product. This room is under the control of a chief draftsman, with section heads, or squad leaders, who are responsible for their own sections of the work. Thus, an automobile chassis may be divided into steering gear, engine, front axle, gear box, differential, rear axle, and so on, each part being allocated to a particular squad. In some firms the designing staff is kept separate from the draftsmen, the latter being employed on detail work only. Newbury[1] describes an arrangement in which the department is divided into a number of design divisions, each consisting of fifteen to fifty people. These divisions are complete with engineers, designers, draftsmen, and are supervised by an engineer-executive, who directs and co-ordinates the work of the engineers and draftsmen. They are divided into small squads, each in charge of a qualified designer, and are specialized both as regards the work assigned to the squad and that given to the individual members. He remarks that "it is not efficient to have designers making working drawings, nor is it wise to entrust very much designing to less qualified detail draftsmen." The flow of work through the department, and its assignment to the squad leaders, is controlled by a production supervisor, who has no responsibility for drafting arrangement. With reference to the squad system it is claimed that "even good men can function successfully and with speed only when they are free to act in relatively small groups."

A firm handling a variety of products may be divided into a number of departments, which are really sub-factories, each being provided with its own drafting room. The departmental manager is the general supervisor, and has control of all drafting in that department. This method, however, lacks the co-ordination of a single drafting room, and is seldom used in modern plants. A system sometimes employed is a modification of the sectional method described above, illustrated by the

[1]"Improved Drafting Management," *Trans. A.S.M.E.*, 15th April, 1932.

organization chart of the Combustion Engineering Corporation (Fig. VI.2.).[1] There are four main divisions, namely, boiler, stoker, pulverized fuel, and special. Each of these handles two types of design—

1. Specific individual products, which may be standardized.
2. Combinations of these products, for which, in most cases, special drawings must be made.

Each division is complete with squad leaders, checkers, detailers, and bill-of-material clerks. Contracts for a combination of products are assigned to contract engineers who form the coordinating factor between the customer and the supplier in the preparation of designs for that particular job. With him is associated a job leader, who is responsible for all of the drawings made for that contract, and who is the *liaison* officer within the organization. A periodic survey is made of the work in progress by means of a log sheet, which indicates the amount of work in hand for each man.

The necessary flexibility in allocating work may be obtained by transferring work from one squad to another, or by transferring individuals in a similar way, so that all of the men may be kept employed.

Procedure.

When work is being performed to special order or contract, the following steps are usually necessary between the receipt of the inquiry and the beginning of manufacture—

1. Receipt and acknowledgment of inquiry. If a quotation cannot be sent immediately, the reply should indicate the probable date when the information will be available.
2. Decision as to size and type of apparatus to be quoted. In some instances a standard product will be suitable, but in others it will have to be modified, or a new design prepared.
3. Preparation of general arrangement drawings and important details.
4. Calculation and tabulation of quantities of material.
5. Writing for tenders in cases where work has to be supplied by outside firms. These letters should be sent out as early as possible so that the tenders may be received in good time.
6. Preparation of specifications.
7. Estimating labour costs of patterns, castings, forgings,

[1]From "Production Management Applied to the Drafting Department." W. J. Kunz, *Trans. A.S.M.E.*, 15th April, 1932.

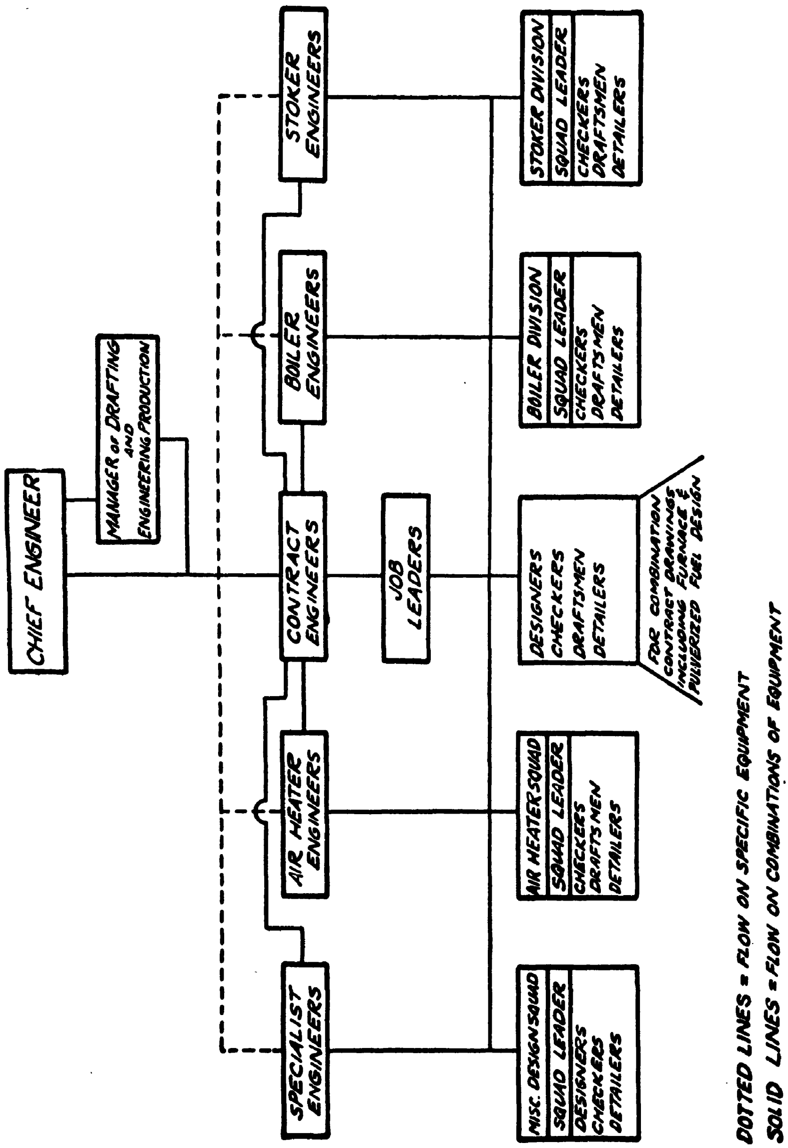


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FIG. VI.2. FLOW CHART FOR COMBINATION CONTRACTS IN DRAFTING DEPARTMENT

machining, and erecting work. These should be given in hours so that changes of wage rates will not make them all obsolete.

8. Estimating cost of packing and transport.

9. Detailed estimation of cost of materials and workmanship. Add overhead and fixed charges, plus a small amount (say, 5 per cent) for contingencies; cost of outside work, packing, and transport. For special work the cost of patterns may be included. In other cases, a percentage of the cost of patterns may be added.

10. Estimating total weight and dimensions of the product, in the packed and unpacked states. For light materials, tonnage is rated by volume.

11. A schedule of the weights of the various materials used is sometimes required for customs purposes.

12. Sending complete estimate with general arrangement drawing and specification to the Sales Department, for adding selling charges and profit.

13. Quotation or tender sent to customer by Sales Department.

14. Order received and copy sent to head of Drafting Department.

15. Detail drawings and jig and tool drawings prepared and sent to Planning Department or shops.

16. Material ordered and manufacture commenced.

Detailing and Filing.

After the calculations have been finished and the general arrangement drawings have been made, the various components of the job are dissected into the details which have to be made individually. These details may subsequently be divided into operations which are separately described, but, from a drafting standpoint, the individual component may be considered as the production unit. This piece must, therefore, be named and numbered so that its functions are indicated and its filing and indexing are facilitated. In many cases it is convenient to designate the patterns or dies by the same part or drawing number. This saves cross indexing and avoids possible confusion. Printed title blanks (Fig. VI.3.) are frequently used on the tracings, for the sake of economy and uniformity, and standard sizes of drawings are used for convenience in filing. After the detailed drawing is finished it is usually traced, checked, and blueprinted. In checking, the dimensions on the drawing should be

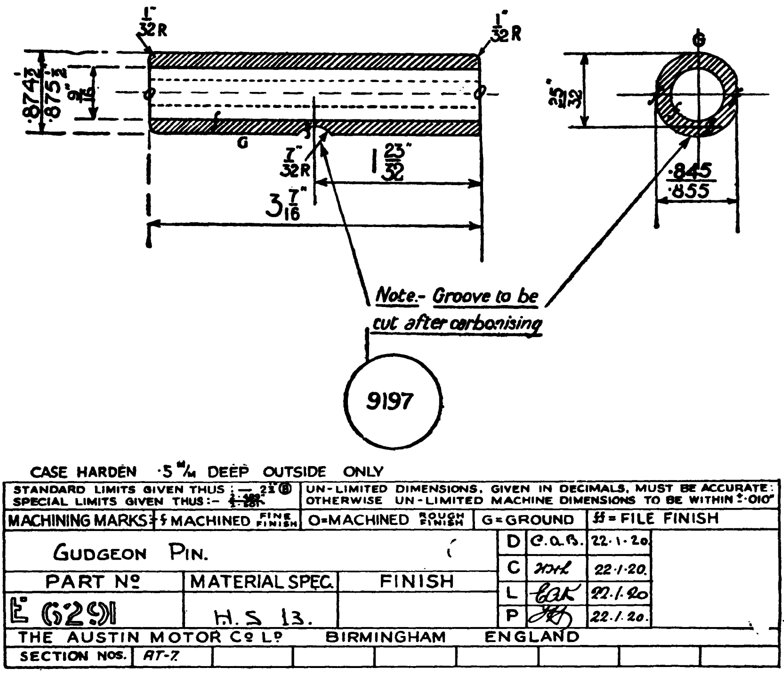


FIG. VI.3. METHOD OF RECORDING ALTERATION TO DRAWING

considered in relation to the probable sequence of manufacturing operations, and so arranged that there will be a minimum of adding and subtracting to be done by the men who have to make the part.[1] This is particularly important where *limits* are concerned, as the errors involved may be cumulative. As all engineering work is approximate, the utility of any job depends upon the permissible limits of accuracy, and the *error* may be described as the amount by which the actual dimension exceeds or falls short of the perfect quantity desired. The checker must see that the limits stated in the drawing agree with the standards in general use for that class of work, and must also guard against *mistakes* which are personal in origin and unlimited in extent.

Newbury describes a system in which all detail draftsmen check their own work. He states that "carefully maintained records have shown no increase in errors per drawing due to this system." Except in special cases, tracing has been eliminated by

[1]See "Trends in Shop Practice and Drafting," *Mechanical Engineering*, July, 1938, p. 547; also "Draughting Practice Relative to Interchangeable Components." Paper read by C. A. Gladman before the Institution of Mechanical Engineers, abstracted in *Manufacturing and Industrial Engineering*, October, 1946.

many firms, reproductions being made from pencil drawings by a photo-lithoprint process.

Standardization of details that are common to particular classes of product is very important, and the checker must consider, in each case, whether a standardized part can be substituted for the new design.

Tracings and original drawings should be kept in fireproof vaults, but this precaution is not necessary with blue-prints. A record should be kept, however, of prints which go into the shops or stores, so that they can all be recalled, if necessary. The shop prints are usually kept in special stores, and are issued in the same way as tools. They are generally mounted and varnished for purposes of preservation.

Alterations.

Changes in drawings and patterns are prolific sources of mistakes. When alterations are made, their influence on surrounding details is sometimes wrongly estimated or overlooked altogether. In other cases, the drawings and patterns are altered to suit a special job, and then are not restored to their original form for standard production. A record should be kept of all such changes and of their nature and extent. In some instances it is advisable to give to the altered drawing or pattern an entirely new number, so that such mistakes may be avoided. This is very important in the case of repair or service work, where an order may be received for a component the form or dimensions of which have been changed since the original machine was sold. Considerable trouble and irritation are likely to ensue if a standard part is sent, and a record of the original dimensions must exist to enable correct replacements to be made.

For this reason, also, no deviation from dimensions given in the drawings should be allowed in the shops. If it is necessary, for some reason, to depart from standard dimensions, a record of the fact and the number of the job affected must be kept on file in the office.

If the drawing number is not changed, a record may be made on the face of the drawing. Fig. VI.3. illustrates a change in the method of manufacture, indicated by the note "groove to be cut after carbonizing," and by the figure 9197 within a circle. This refers to the number of the alteration note, which records the date, the nature of alteration, and the number of the first machine affected by the change. An alternative method of record-

ing is to make a note of these facts on the tracing itself, but frequently this is inconvenient.

When alterations are made, all blue-prints in the shop should be recalled and cancelled, so that obsolete drawings cannot be used. Unless the number and destination of these prints are recorded, it is impossible to be sure that all of these prints have been removed. Similar precautions are necessary in connection with the stores, where old and new designs should not be mixed.

All changes cost money, and this fact is recognized when material or equipment is affected, because the results are tangible, but it is frequently overlooked where drawings are concerned, because the expenditure is not so apparent. It is necessary for all industries to furnish the best possible designs, and therefore some changes *must* be made, but they should not be undertaken lightly, or as the result of a whim. Drawing costs which exceed the original estimate encroach on the final profits.

Drawing Costs.

The use of time cards in the Drafting Department is advisable, so that the cost of each drawing may be estimated with reasonable accuracy. Kunz[1] describes an elaborate system for checking the amount of work done and outstanding, and for seeing whether the costs are within the original estimate. He states that the cost of doing this varies from 0.5 to 0.7 per cent of the Drafting Department payroll. Newbury[2] gives details of a "par time" plan, in which a standard time allowance somewhat similar to that used in the shops is employed, as a basis for bonus systems of payment. The "par time" covers the making and checking of the pencil drawing when all necessary information is available, and when working conditions are ideal. The records show that, in the beginning, the actual time taken exceeded "par time" by a considerable margin, but that "par time" was achieved in about nine months after the adoption of this system.

Obviously, the attainment or otherwise of the "par time" depends upon the man who sets the time and on the method by which it is calculated, but the experiment is an interesting one. It is an attempt to run the Drafting Department on lines similar to those of the shops, but with the difference that the rate of pay of the draftsman is not based directly on his performance ratio $\left(\text{i.e. } \frac{\text{actual time}}{\text{par time}}\right)$. His salary is affected by this indirectly, how-

[1]Loc. cit. [2]Loc. cit.

ever, as it is used as a guide to judgment when increases of pay and promotions are being considered. Also, individuals who fall considerably below average performance are removed or transferred to other work, thus increasing the efficiency of the staff.

CHAPTER VII

PURCHASING

The importance of the buying operation to engineering firms varies with the ratio of material to labour cost in the final product. If this is high, or if large quantities of material are bought annually, considerable savings may be made by judicious purchasing, or heavy losses may be incurred as a result of wild or speculative buying. It pays, therefore, in these cases to spend large amounts of money on the Purchasing Department. On the other hand, many firms buy relatively small quantities of standardized material, the value of the product being due almost entirely to the labour expended upon it. The elaborate and costly system that is necessary in the former case would be far too expensive for application in the latter. The average division of the "manufacturer's dollar" indicates that, in general, the gross sales must be increased considerably to compensate for injudicious buying.

The personality and experience of the chief buyer or purchasing agent is a matter of great importance, as his knowledge of the materials to be bought and their peculiarities will enable him to recognize the *essential* properties in the alternative materials offered for a given service. Familiarity with the processes through which the material must go will sometimes justify slight changes of specification, thus facilitating delivery without impairing the usefulness of the article. Such a procedure is dangerous, however, without full knowledge. Technical training is a decided asset in this connection. The necessity of absolute honesty on the part of the buyer is evident, as his position makes it easy for him to obtain numerous perquisites from suppliers to the detriment of the firm which employs him. Tact and sound judgment are also desirable assets.

Policy.

The fundamental principles to be observed in purchasing have been described by Rautenstrauch.[1] The answer to the question as to whether certain parts shall be purchased from outside suppliers or manufactured at home depends upon the following considerations:

[1] "The Economics of Purchasing," *Mechanical Engineering*, October, 1934.

(*a*) What is the relative return on the investment to provide for the manufacture of certain parts as compared to purchasing them ready for assembly or even in a semi-finished state?

(*b*) Is the supply of the parts which may be purchased adequate to ensure regularity and the maintenance of low prices in competitive bidding?

(*c*) Shall certain parts which are patented but which can be purchased from other manufacturers be used, or is there a danger in their use because of the question of patent validity?

(*d*) Of parts which may be purchased from any of several manufacturers, which has the greatest public acceptance?

(*e*) If a given part is purchased from another manufacturer, what servicing can and does this manufacturer provide to the users of these units?

(*f*) Is the quantity of any part of the product to be manufactured too small to justify the investment in special machinery required to produce it, and would it be advisable to purchase these parts from others better equipped for this work?

(*g*) Shall a complete line of sizes and styles (valves, for example) be manufactured or shall the business be devoted to manufacturing a few styles and sizes?

All of these questions have a direct bearing on what manufacturing facilities shall be provided and on the capital requirements of the business. The products should be carefully examined with respect to these particulars before any steps are taken to provide manufacturing facilities.

Centralization.

Authority to purchase material may come in the form of requisitions to a central Purchasing Department from which all orders should be sent. The reasons for this are given in full by Gushée and Boffey[1] and other writers, and may be summarized as follows—

1. Undivided responsibility is placed in the hands of those having most knowledge of, and experience in, buying.

2. There is a reduction in the variety of material bought.

3. Purchases in large quantities are possible, and therefore prices are low.

4. A check is provided on excessive consumption and economy is encouraged.

5. Purchases may be made at the best times when there is a fluctuating market.

[1] "Scientific Purchasing," p. 14.

6. The use of standard specifications is facilitated.
7. The verification and approval of material, and payment of bills are simplified.

Savings of from 10 to 25 per cent in the cost of materials are claimed for centralized, as compared with departmental, buying.

Equipment.

The duties of this department include not only requisitioning materials and placing orders, but following up until delivery is obtained and frequently also checking the goods when received. The organization and equipment, therefore, must be arranged conveniently for these purposes. Catalogue files, indexed and cross-indexed, provide information relating to available sources of supply for specific materials, and records of the average rates of consumption with sizes of previous orders indicate probable future requirements. The location and transport facilities of supplying firms, together with information regarding their productive capacities, indicate the places where inquiries may most profitably be made. Records of previous shortages or delays in delivery and of defective material received, are also useful. Prices previously paid, with discounts or rebates, are an essential part of these records.

Operation.

The first step is the receipt of a requisition for the material needed. This may originate from the stores, planning department or elsewhere. The order must then be placed and followed up until the goods are received, when they must be checked for quality and quantity before the account is passed for payment. The placing of the order involves four principal questions, namely—

1. What material is to be bought?
2. What quantity is to be supplied and at what rate of delivery?
3. Who is to supply it?
4. What price is to be paid?

After these points have been decided, it is necessary to provide for the verification or inspection of the goods on arrival, or alternatively, at the suppliers' works, so that unsatisfactory material may be intercepted before it reaches the stores. It is also desirable that the Purchasing Department keep in touch with the Design and Inspection Departments, to prevent the pur-

chase of unnecessarily expensive materials and unsatisfactory supplies. The importance of adequate specifications has already been indicated (Chapter II), but in spite of this, material is frequently bought by brand or sample. This procedure is commented on by the United States Bureau of Mines in Bulletin No. 41[1] as follows—

Under the old plan of purchasing coal, when the consumer had cause or thought he had cause to find fault with the quality of the fuel he received, he was assured that it must be good because, like all the other coal sent him, it came from a mine with an established reputation. Such a state of affairs made it difficult to take advantage of the competition which usually results from a considerable number of bidders being asked to submit prices. The purchaser was afraid to buy from any dealers but those he knew and trusted, because, although each dealer claimed that his coal was equal in quality to that of the others, yet if it did not prove to be satisfactory there was no standard of settlement.

Many thousands of dollars worth of coal is still bought each year in this manner, yet a buyer or investor should consider it absurd to make a contract for a building with no specification other than that it should be of a certain size and well constructed. Neither would he buy gold, silver, nor even copper or iron ores on the mere information that they were mined at certain localities.

The disposition of surplus and obsolete materials and equipment is also frequently considered to be an incidental responsibility of the purchasing department.

Quality of Material.

The term *raw material* is a relative one, as the finished product of the blast furnace is the raw material of the foundry, and that of the latter is the raw material of the machine shop. Engineering materials are bought in many stages of completion. Some components or accessories are purchased in the finished state, and have only to be used in the final assembly. Others are partly finished and have to be processed to a less or greater extent before erection can begin. The quality required is usually indicated by the specifications, as described above, but two factors call for further comment at this stage, namely, *uniformity* and *suitability*.

The specification fixes the minimum standard of quality, but there are some deviations from this standard that the prescribed tests do not detect. A case of this kind occurred in a large automobile firm where certain forgings were tested and passed before

[1]Taken from *Purchasing*, Rindsfoos, p. 11.

entering the stores. During the machining process hard spots were encountered in the material. These ruined the tools and made it impossible to complete the work. Another example occurred in connection with a consignment of bright drawn steel. The preliminary tests failed to disclose the fact that about 2 per cent of the bars were harder than the rest, and the dies were spoiled every time one of these bars entered a machine. It was necessary to recall all of this material from the shop, and to test every bar before it was put into production. This want of uniformity and its sequel cost the firm far more than the material was worth.

The question of the suitability of material is important, because the cheapest material may involve high manufacturing costs. This was exemplified in the case of a large firm making drop forgings, where a certain part was specified to be made of medium carbon steel. This material, if properly heat treated, was quite satisfactory, but the forging and heat treatment operations had to be performed with such exactitude that upwards of 30 per cent of the forgings were rejected in the subsequent manufacturing processes. A more expensive alloy steel was substituted, and the amount of scrap was reduced to less than a half of 1 per cent. This effected a considerable saving in the final cost in spite of the more expensive material employed.

Another example of unsuitability is given by Rindsfoos,[1] who describes the purchase of a number of locomotives that were too long for the turntables available. It proved cheaper to sell the locomotives than to change the turntables.

Materials of the same kind but from different sources may vary considerably as to quality. Kelleher and McGeary[2] indicate the variety of serviceability revealed by tests on piston rod packing for the United States Navy. Of the twelve brands tested—

(*a*) The weights required varied from 1.8 to 3.12 lb.

(*b*) The frictional loss varied from 0.97 to 1.73 H.P.

(*c*) The endurance varied from 371 to 2056 hours.

Assuming uniform price, it was found that 68 per cent greater service was obtainable from the best material as compared with the worst.

Quantity of Material.

The amount of material to be purchased from year to year depends upon the manufacturing programme, which is now fre-

[1] Loc. cit.

[2] *Manufacturing Industries*, July–September, 1928.

quently controlled by a budget. The quantities to be bought from a particular firm, however, and the time or rate of delivery are matters of great consequence. The ideal arrangement is to have the material delivered at the moment when it is needed for production purposes, but this is generally impracticable owing to conditions of transport and supply. Maximum and minimum limits are, therefore, fixed for the stock of each part, and these are frequently chosen arbitrarily on the basis of past experience rather than on future requirements. In most cases the quantity *ordered* is the difference between these two. Davis[1] has worked out a series of formulae in which the maximum and minimum ordering quantities are indicated mathematically. The actual formulae may be seen in the original paper, but the following remarks are taken from the context to indicate the economics of this procedure—

The quantity ordered may be controlled by means of the balance-of-stores ledgers. In many cases a quantity, usually called the maximum ordering quantity, appears on the ledger sheet for each item carried in stock. This is a predetermined quantity intended to limit or specify the quantity which shall be ordered at any one time. If too little is ordered at any one time, the unit cost of procurement will be too great. The cost of procurement includes such items as the expense of originating the purchase requisition, the time of major executives spent in consummating the purchase, the time of buyers and clerks spent in investigating markets, securing bids, and placing purchase orders, time spent in following up the order, the expense of receiving and inspecting the goods, the expense of stowing, the expense of closing out purchase orders in the purchasing and accounting departments, and similar items. The determination of this value for a given item means considerable analysis. However, when once determined it stands as a standard cost until there is a considerable change in conditions.

As the quantity purchased at any one time increases, the unit cost of procurement decreases, but the unit interest and storage charges increase. The total unit cost of the item decreases up to the point where increasing unit interest and storage charges outweigh decreasing unit procurement charges. Beyond this point the total unit cost increases. Obviously, the maximum ordering quantity should be such that it will hold the total unit cost at this turning point.

The storage charge depends on the unit storage space required, the cost of storage space, and the time of consumption.

In the discussion of this paper Flack pointed out that the practical application of these formulae is affected by such variables as seasonal demands, changes in style or price, changes in

[1] "Determination of Minimum Cost Purchasing Quantities," *Trans. A.S.M.E.*, January–April, 1928.

manufacturing or marketing methods. Also methods of purchasing vary with the production requirements, as follows—

1. Regular and predetermined quantities.
2. Predetermined quantities at irregular or uncertain intervals.
3. Large quantities at widely-separated intervals.
4. On schedule, in cases where no stock is carried.
5. Varying quantities and times of delivery (e.g. tools).

Transport costs also enter into the picture and, as a general rule, it is advisable to order in good time so as to avoid express deliveries. Proper grouping of orders may also make it possible to economize by substituting a small number of large consignments for a large number of small ones.

Supplying Firms.

In most cases, the choice of supplier depends partly on prices and partly on the previous experience of the buyer. The reputation of a firm for straight dealing, and for keeping its promises of delivery, is frequently an important factor. The possible sources of supply may be numerous or few, but in most cases there are some producers who have the best experience in supplying the material required. These are generally to be preferred (other conditions being equal) as they usually have adequate financial and manufacturing facilities for carrying out the order.

Sometimes it is advisable to forego a price advantage in order to obtain the protection of the better financial rating of a particular supplier, or to distribute orders among a number of manufacturers so that a fire or strike may not cut off all supplies of a particular material.

A common practice is to compile "approved lists" of products and suppliers for each regular requirement and the purchasing department then selects the supplier from these lists.[1] A policy of reciprocity, whereby the desirability of a particular supplier is based largely on his value as a customer is generally undesirable, as it is influenced rather by the sales policy than by the procurement function of the firm concerned.

Price.

It has been indicated that while price is a prominent characteristic, it is not the only one to be considered, and for this reason it has been placed last on the list. Many buyers act as if low first cost were the only criterion, whereas the lowest price is

[1] "Purchasing," S. F. Heinritz, *Trans. A.S.M.E.*, April, 1943, p. 215.

not necessarily the best. The price actually paid depends partly upon the number of sources ~~available; the~~ greater the competition the lower the price (until at length the competitors get together and fix the price between them). In some countries certain supplies have become practically domestic monopolies, and it is found to be cheaper to buy from foreign firms.

The distance and method of transportation are also prominent factors in price. The province of Ontario has no coal, but most of the large industries are located there. The extreme east and west of Canada have large quantities of coal, but no market for their product. Many of the miners are unemployed because the cost of carrying the coal to Ontario makes the price prohibitive. Consequently, most of the coal used in Ontario comes from the United States, because their coal-fields are relatively near.

Curves showing the fluctuations of prices must be studied, and seasonal rises and falls must be utilized to the best advantage. If the material cannot be used in a reasonable time, the cost of storing material is an offset to the saving obtained. In some cases, quotations are based on a sliding scale, rising or falling in accordance with the cost of labour. Power should always be retained to terminate a contract by giving due notice.

Discounts and terms of payment are important in any contract. The larger the terms granted by the seller, the less must be the borrowed working capital. Cash discounts are not always assessed at their true value. If the terms quoted are "2 per cent in 10 days, or 30 days net," this means that if the bill is not paid in ten days, the debtor prefers to wait twenty days more and to pay 2 per cent for the accommodation. *This is equivalent to paying interest at the rate of 36 per cent per annum.*

Bonus and penalty clauses[1] are sometimes included in the contract for improving on, or failing to adhere to, the promised delivery date. These are sometimes advantageous, but the amount of bonus or penalty should not be out of proportion to the advantage accruing from early delivery, or to the damage resulting from late delivery.

[1]*Engineering Law*, Laidlaw & Young, p. 100.

CHAPTER VIII

BUDGETS

The application of budgets to business is of comparatively recent origin, but the advantages of forecasting manufacturing, selling, and financial programmes with reasonable accuracy are so obvious that the increasing use of this method of control is not at all surprising. The increasing use of budgetary control is a direct outcome of the growth of businesses and the consequent delegation of authority and responsibility described in Chapter I. A specialized business, particularly one of large size cannot adapt itself readily and quickly to changing conditions and therefore, some logical forecast must be made concerning the amount and nature of its future activities. Budgeting therefore substitutes considered intention for opportunism in management. It is claimed that the cost of preparing and handling the budget is very small. Numerous instances are given in the technical press of budgets being realized in practice within 5 per cent or less.

In addition to forecasting the amount of business, the budget indicates the costs of manufacture and distribution, plans the financing, and shows the probable profit. Anderson[1] describes it as a guide to performance and a check on accomplishment. The principal difference between national (or governmental) and business budgets is that, in the former, income and expenditure are largely independent of each other. The government estimates the probable expenditure and devises suitable taxes to meet it. Decrease of expenditure does not usually lead to loss of income. On the other hand, with a business, a reduction of expenditure in advertising, equipment, stores, etc., frequently does lead to loss of income by reducing production or sales. This interdependence makes the preparation of the budget more difficult, but it emphasizes the necessity for adequate coordination between the respective functions of production, sales, and finance. The term *estimate* is generally understood to refer to a particular job or contract, but a budget is a forecast of the operation of the business as a whole for a definite period.

[1] *Industrial Engineering and Factory Management*, Chap. XXVII.

Sales Budget.

The manufacturing programme depends on the amount of goods that is expected to be sold. This may be estimated from analyses of past sales modified by trade prospects, salesmen's experience and plant capacity available. Other factors are possible modifications in the form or quality of the product, or the financial capacity of the firm, which may limit the possible expansion of the market.[1]

The market may also be affected by the age group or income group in which most of the prospective customers are to be found, or by the nature of the product. The demand for bread, for instance, is not affected by changes in price to the same extent as the demand for luxury articles.

TABLE I

Ratio	Year					Maximum or Minimum
	1942	1943	1944	1945	1946	
	%	%	%	%	%	%
Cost of Sales / Net Sales	79.9	79.2	78.1	77.8	80.1	75
Mfg. Expense (Burden) / Net Production	29.4	24.0	26.8	26.1	23.5	22
Mfg. Expense / Net Sales	24.5	22.0	24.3	24.7	20.2	20
Raw Material Inventory / Net Production	40.1	42.0	41.9	39.8	38.9	35
Process Inventory / Net Production	30.1	32.0	31.0	29.9	29.2	26
Direct Material / Net Sales	37.5	35.2	37.2	38.5	39.1	35
Direct Labour / Net Sales	23.4	22.8	20.9	21.7	22.0	20
Indirect Labour / Direct Labour	47.0	46.5	46.1	45.8	45.2	40
Finished Goods Inventory / Net Sales	10.8	10.4	10.1	10.5	10.0	10
Total Inventory / Net Sales	24.3	24.0	23.8	24.2	23.0	20
Fixed Expenses / Total Mfg. Expense	28.1	28.3	27.9	27.2	27.5	25
Working Capital / Net Sales	35.1	34.8	35.5	34.2	33.1	30
Gross Profit / Net Sales	21.1	20.9	21.9	22.2	19.9	25
Selling Expense / Net Sales	10.9	11.0	11.4	12.2	12.5	11
Net Profit / Net Sales	4.3	4.7	5.1	5.5	3.9	5

[1] *Budgetary Control and Standard Costs.* Scott.

Marketing research is divided by the American Marketing Association into four main categories[1]—

1. *Policy research*, which covers advertising, allowances, cancellations, compensation, credit granting, pricing, public relations, etc.

2. *Product research* includes new products, change of form or properties, comparisons with competitors' products, new uses, packaging and sample testing.

3. *Market research* covers analyses of sales territories, wholesale markets, statistical analyses, business forecasting, classifications of potential purchasers, sales quota, etc.

4. *Methods and means research* covers competitors' practices in advertising and selling, distribution costs, brand preferences, channels of distribution, training of salesmen and other related topics.

The analysis of past performances is assisted by a tabulation of significant ratios as in Table I.

There are no standard ratios for any particular kind of industrial work, but actual values must be obtained from previous records and compared with such similar ratios as can be obtained from other firms which operate under similar conditions. Abnormal values of these ratios constitute danger signals and indicate weak spots in operation.

Production Budget.[2]

This is based on the sales budget and indicates the expected or desired output during the budgeting period. Some conditions are difficult to forecast and the budget must have sufficient flexibility to allow for these deviations, but budgetary operation may indicate the necessity of making changes in direction or procedure to reduce them. No budgeting system can work successfully without the full support of the management.

Bracketing shots are used in artillery practice to creep ever nearer to the target, and similar trials are necessary in budgetary control. The shorter the period for which the budget is prepared, the more accurate are likely to be its provisions. Frequent budgeting, however, is expensive, and after some of the inaccuracies have been eliminated, the period covered should be the longest possible, consistent with the minimum business hazard. This will vary in different industries, but it depends on—

[1] "Industrial Marketing," H. J. Loberg, *Trans. A.S.M.E.*, April, 1943, p. 230.
[2] *Flexible Budgeting and Control*, Garden; *Business Budgets and Budgetary Control*, Willsmore.

1. The normal business risk.
2. The stability of the market.
3. The method of financing, production, and determining inventories.
4. The scheduled period of production.
5. The duration of the reporting and accounting period.
6. The amount of information available on past performances.
7. The merchandising inventory turnover period.
8. Periodic fluctuations of supply and demand.

In some instances general policies are embodied in a long term budget, while the operating budget, which is drawn up in greater detail, is arranged for immediate use over a shorter period.

The points at which no profit or loss (*break-even points*) occur must be found for the expenses as budgeted for the various departments, and for the volume of sales for each class of product. An example of this is given in Table II, where the break-even point occurs between 600 and 700 thousands of dollars. The productive capacity of each department and section must be determined, and market surveys will indicate the minimum quantity that the market will absorb at those price levels.

The effects of variations in selling price on sales volume and gross profit may be estimated in a similar manner.

The budget, as adopted, constitutes the standard of performance for the prescribed period, and limits should be established for the expenditure of each department or section, which should not be exceeded without permission from the properly constituted authority.

The material side of the production budget is fairly simple to handle, but the labour budget is more difficult, particularly when goods are made to order. In such instances, there is a wide variation both in individual operations and in combinations of operations, but if methods are standardized, some of the difficulties are avoided.

The various individual budgets, such as those for plant and equipment, manufacturing expense, general expense, etc., are combined in the financial budget which summarizes the expected incomes and expenditures. From this, a balance sheet and profit and loss account, which will form bases of comparison for the actual results, can be forecast. From this master budget and the individual budgets which contributed to it, the executives

TABLE II

COMPARATIVE RESULTS OF OPERATIONS FOR DIFFERENT SALES VOLUMES[1]

Sales in thousands of Dollars	500	600	700	800	900	1000	1100	1200
	%	%	%	%	%	%	%	%
Sales	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Materials	40.3	39.4	38.5	37.8	37.2	36.7	36.7	36.7
Direct Labour	28.0	27.5	27.0	26.5	26.0	25.5	25.5	25.5
General Factory Expense	20.0	19.0	18.0	17.0	16.5	16.0	15.5	15.0
Cost of Sales	88.3	85.9	83.5	81.3	79.7	78.2	77.7	77.2
Gross Profit on Sales	11.7	14.1	16.5	18.7	20.3	21.8	22.3	22.8
Selling Expenses	8.0	7.7	7.5	7.3	7.1	7.0	6.9	6.8
Selling Profit	3.7	6.4	9.0	11.4	13.2	14.8	15.4	16.0
Administrative Expense	10.0	9.0	8.0	7.0	6.5	6.0	5.9	5.8
Operating Profit	6.3[2]	2.6[2]	1.0	4.4	6.7	8.8	9.5	10.2

can determine causes of failure to realize the predetermined programme, and can apply the necessary corrective measures.

The advantages of budgeting are classified by Anderson,[3] as follows—

1. All important production and sales factors are fully investigated.

2. Individual and departmental activities are harmonized and directed to a single end.

3. Policies are translated into working plans, and responsibilities are definitely allocated.

4. A convenient check on accomplishment is provided.

5. Losses are prevented by prompt indications of deviations from plan.

6. Sales and production programmes are synchronized in advance.

7. The existence of a definite objective promotes better accomplishment.

8. Improved performance provides a basis for new standards.

9. The employment of labour is stabilized by filling up some of the hollows in the production curve.

10. The stock of raw and of finished material is reduced to a minimum.

11. Capital can be used more economically on account of the improved load-factor.

12. Better financial arrangements can be made, as a budget assists the bank by determining the amount of credit that can

[1]By Bigelow Kent Willard & Co.
[2]Loss.
[3]Loc. cit., p. 457.

be allowed, and the firm by deciding the amount of loans that are needed.

The Break-even Chart.

The information given in Table II may be indicated more clearly and conveniently by the Profitgraph or Break-even Chart. In this diagram, sales volume or plant output is plotted as abscissa, and the corresponding fixed and variable items of cost as ordinates, giving the total annual cost of the goods produced and sold. The line representing the income from sales obviously goes through the origin, and the point where these two lines cross is called the "break-even point." If the actual output or sales volume is above this, a profit is made, and, if below, there is a loss (Fig. VIII.1.). These charts are being used to an increasing extent for budgeting purposes, and a complete example of their use in the manufacture and distribution of yeast is given by Rautenstrauch.[1] They have also been used satisfactorily in a small furniture-making business, so that their application is not restricted to large mass-producing or distributing organizations.

Weart remarks[2]—

> The true difficulty in plotting the chart lies in determining which expenses are truly fixed, which truly variable, and which partially each. Regardless of whether or not the chart is infallibly accurate, it has already served one useful purpose—pointing out to industry the fact that the high fixed expense inevitable when a plant is highly mechanized reacts very unfavourably upon that plant and upon the trade as a whole in times of shrinking volume.
>
> The more practical aspects of fixed expense in its relationship to day-by-day operation of a business enterprise are receiving more attention, primarily because the depression has forced managers to make reductions in "fixed" expense that had not previously been considered possible. The lesson learned from the 1921 depression was that excessive inventories were dangerous; the lesson from 1931 seems likely to be a knowledge of the evil effects of too great a plant capacity. Many executives are now learning that in expanding plant capacity, any increase in fixed expense should be so regulated as to be absorbed without increasing unit cost beyond normal bounds, within the period of anticipated increased production, conservatively estimated.

The problem of dealing with "semi-fixed" expenses, that is, those expenses which vary to some extent with activity, is dis-

[1] "Budgeting an Industrial Enterprise," *Trans. A.S.M.E.*, November, 1934; Paper, MAN 56–2.

[2] "Recent Developments in Managerial Methods in the United States," *Engineering*, 24th August, 1934, p. 210.

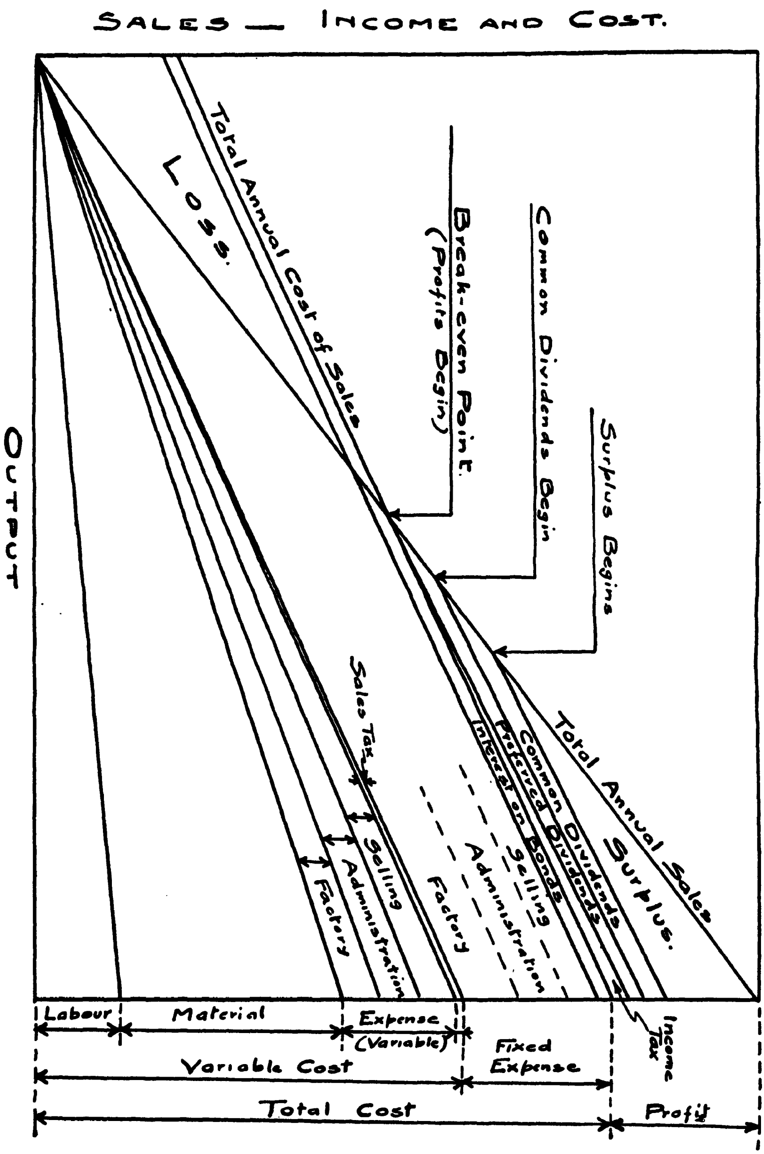


Fig. VIII.1. The Break-even Chart or Profitgraph

cussed by Mallory.[1] This analysis includes the reduction of staff or salaries in slack times and results in a modified total cost which is not necessarily represented by a straight line. The chart is similar in form, however, and is used in the same way.

Analyses of the relationship between incomes and expenditures of a wide range of types of business over a period of years are given in a paper by Rautenstrauch[2] and these give useful and important applications of the break-even chart.

Budget Officer.

Some independent member of the staff must be made definitely responsible for the budget but, in large organizations, the detail work and necessary revisions are handled by a committee chosen from the various departments concerned. The budget officer sees that standard forms are provided, that the necessary information reaches, and is received from, the departmental heads at the proper times, advises the budget committee, puts its decisions into operation and compares actual results with the budget forecasts.

Reasons for Failure.

Budget systems are not invariably successful and Willsmore[3] lists the following typical reasons—

1. Cost accounting or statistical system inadequate.
2. Bad organization or failure to co-operate.
3. Poor market analyses.
4. Lack of managerial or presidential support.
5. Too much or too little detail—lack of flexibility or precision.
6. Too little advance preparation—results expected too soon.

[1] "The Break-Even Chart—Some Practical Limitations to its Use," by H. R. Mallory, *Mechanical Engineering*, August, 1933, p. 493.

[2] "The Economic Characteristics of Typical Business Enterprises," *Trans. A.S.M.E.*, April, 1937, Paper, MAN 59–1.

[3] *Business Budgets and Budgetary Control*, A. W. Willsmore, (Pitman).

CHAPTER IX

PLANNING

This is an extension of the idea of transfer of skill, in which *thought* is separated from *action*, and is an integral part of the functional system. A careful survey of the facilities available for production, and of the routes over which the material must travel during manufacture, will save considerable trouble and confusion in the shops. It will enable the foremen and men to concentrate on the job for which they are primarily responsible, instead of dissipating their energies along a number of side avenues.

"It is well-established that, if the efficiency of production in an ideal works is represented by 100, the normal average output from a real works where machinery and tools do break down, where workpeople are sometimes absent, where materials and tools are not always ready to time, is anything between 50 and 75 on the same scale. In other words, if the plant and equipment in a given works were fully employed at its due rate during every minute of a working week, the output would be enormously greater than it actually is. Much of this loss is not preventable—or alternatively, to prevent it would cost more in money and trouble than the return; but a good deal of it can be saved very simply by better planning, by anticipating requirements, not trusting to luck, or leaving difficulties to be surmounted by foremen as their opportunities permit."[1]

With repetitive work better means can be employed, and therefore there is greater efficiency and less effort than where miscellaneous work is done. The former is easier to deal with on account of its greater stability, and is therefore better managed.

When the work is of a varied nature, delays for tools and shop transport are common, and there is also a tendency to move men about from one job to another as the incidence of pressure varies. This is wasteful because it transgresses the law of division of labour. In hand work, particularly, it does not necessarily follow that because three men can do a job in twenty hours, six men can do it in ten hours.

[1]"The Profit of Planning;" *Engineering*, 17th August, 1923.

"In the ideal factory the work moves smoothly from station to station where men, suitably equipped, are in just the right force to deal with it in the manner required. And the tendency in repetition work is toward this condition: regular channels of flow become more or less established; there is less turbulence, less appearance of violent energy, and more useful work done."[1]

Gillespie[2] describes how a large shop with an apparently efficient looking system of diagrams and load charts for work progressing had a lag of two months in their delivery dates and over $35,000 worth of work lying around the erecting shop. Improved stores control and a simple system of planning brought the time lag down to as little as four days. Another well known engineering firm found, during stores reorganization, that $20,000 worth of obsolete stock had accumulated, owing to lack of proper control.

The planning function is defined in the two following statements by Alford—

(*a*) THE LAW OF PRODUCTION CONTROL. *The highest efficiency in production is obtained by producing the required quantity of product, of the required quality, at the required time, by the best and cheapest method.*

(*b*) THE LAW OF PLANNING. *The mental labour of production is reduced to a minimum by planning before the work is started,* WHAT *work shall be done,* HOW *the work shall be done,* WHERE *the work shall be done, and* WHEN *the work shall be done.*

The former of these laws indicates the desired objective, the latter designates the steps that are necessary to reach it. The formation of a separate Planning Department or section does not introduce a new kind of work, as the above functions must be performed by somebody in every type of organization, but it does introduce a new way of handling the details. As a general rule when a definite planning scheme is adopted, the overhead expense for clerical work is increased, while that of the shops is decreased to a greater extent, so that there is a net saving. In most cases, also, the need for special pressure at various intervals and in particular spots is removed, as the system is based on *prevention* rather than *cure.*

There are two types of planning, namely, the *empirical* and the *statistical*. The former is based on memory and experience, and is characteristic of the military type of organization, where

[1]"The Profit of Planning," *Engineering*, 17th August, 1923.
[2]"Engineering Works Reorganisation," *Engineering*, January 15, 1937.

the superintendent gives an order to the foreman, and he, in turn, passes it on to the workmen. These have to make their own arrangements for doing the work and must surmount their own difficulties, so that the work usually takes a longer time than it should, and is not done to the best advantage. Taylor dealt with this situation in a machine shop by having separate men to attend to the order of work, to issue instruction cards, to look after questions of time and cost, and generally to separate *planning* from *performance*. These men worked from records of past accomplishment, and were able to establish standards for comparative purposes. Satisfactory planning is thus dependent on the availability of sufficient advance information regarding production processes, and for this purpose the conditions of work must be established fairly definitely. Time and motion study, which will be described in a subsequent chapter, is one of the tools used for fixing time standards.

Planning is not restricted to mechanical production work, but can also be applied in many other directions. At the Hudson Avenue Power Plant (Brooklyn) a yearly boiler schedule is devised to meet all expected daily peaks and to provide idle intervals for inspection and maintenance. Daily boiler and turbine schedules are then prepared from this master plan. The operation of these plans includes systematic coal testing and measurement, provision of proper controls and the training and supervision of personnel.

The Position and Arrangement of the Planning Department.

Methods of production control are both numerous and varied, and it is not intended to describe the different kinds of planning boards and other ingenious devices that have been used in this work. The question of centralization, however, and the inter-connection between the Planning and Production Departments must be considered at this stage.

Complete centralization is only possible in cases where the plant is not too large or too diversified. Large firms having a standard type of output do a certain amount of master-planning in a central department, while detailed work is decentralized. The arguments in favour of this procedure are well put by Anderson[1]—

"If the article is a technical one and department operation is largely independent of other departments, those in immediate charge should be best qualified to plan the work. On the other hand, if the machinery of several departments is utilized in

[1]*Industrial Engineering and Management*, p. 580.

making a variety of articles, central control is essential. When a department consists of a battery of like machines, or specializes in one task, decentralized control is suggested. Routing to a group of machines simplifies control, and the foreman in charge, without need of clerical control, assigns the work to the stations or machines available. Also, production delays are less likely to occur where there is greater flexibility in the use of equipment."

The relationship between the Planning and Production Departments also depends upon circumstances. In some cases, planning is performed by a separate department, independent of, but co-operating with, the Production Department. In others, the planning section is a part of that department and is subordinate to the production manager. Its operations also depend to some extent on its powers. In some instances the object of planning is to make the best use of existing equipment and men; but in others the work of the Planning Department includes the re-arrangement of existing equipment or its replacement, and the criticism of designs from a production standpoint.

Duties of the Planning Department.

These include routing, scheduling, and dispatching, and occur in that order.[1]

(*a*) ROUTING. This consists firstly of the analysis of the work into its components, and the arrangement of a sequence of operations for each element that will bring the various parts together at the right time and place. It also involves the consideration of material supplies, and the investigation of production facilities and plant lay-out. Job studies are necessary to indicate where, and by whom, the various manufacturing operations can be performed to the best advantage, and this affects also the sizes of lots or batches that can be handled most conveniently and economically.

(*b*) SCHEDULING. If routing provides the answer to the questions "*how*" and "*where*" scheduling indicates *when* the work shall be done. It consists of the arrangement of a time-table of operations within the prescribed routes, in such a way that all machines and men shall operate at their maximum productive capacity to satisfy the requirements of the Sales Department. The relative importance of the various manufacturing orders is indicated by a master schedule which may be

[1]These matters are discussed more fully in *Work Routing, Scheduling, Dispatching*, by Younger and Geschelin (Ronald Press) and in *Plant Production Control*, by Koepke (John Wiley).

prepared either before or at the same time as the routing operation. Detail schedules follow the routing process and determine the order of work in point of time. The Gantt and other types of progress and load charts provide the information necessary to give up-to-date information upon which changes in the order of work can be based, and indicate where pressure can be applied to the best advantage.

(*c*) DISPATCHING is the *operation* of the schedule. It comprises the issuing of stores, time cards, control forms, and tools in such a way that routes and schedules will be followed and the plan carried out. This process has been likened by Kimball[1] to the work of a train dispatcher, the object being to start a piece of work at a given time, and to direct its progress in point of time and place until it is completed. Methods of *tracing* and *following-up* work must be devised to allow a continuous record to be kept of all material that is passing through the factory[2].

Progress departments or sections are sometimes organized for this purpose, some system being necessary for maintaining a continuous check on the manufacturing operations. It is sometimes too expensive to provide a special department, but almost invariably some suitable arrangement can be made.

In a small firm the author used successfully the device of making the returns from the line inspectors in triplicate by means of carbon copies. One copy went to the chief inspector and another to the progress clerk. The latter was thus kept continually advised of the passage of material through the various departments and important processes. The whole progress system was operated in this way by one extra man on the staff. This method is not suitable for all cases, but others can be devised to suit particular classes of work.

[1]*Principles of Industrial Organization.*
[2]See also *Plant Production Control*, C. A. Koepke, Chaps. XVI–XXI.

CHAPTER X

RECEIVING, HANDLING, AND STORING MATERIALS

Laws of Material Control.

The principles that control the handling of materials used for manufacturing processes are summarized by Alford[1] in the following two laws—

1. *The highest efficiency in the utilization of materials is obtained, by providing the required quantity of the required quality and condition at the required time and place.*

2. *The highest efficiency in the storage of materials, tools and supplies, is obtained by providing a definite place to store every item, keeping every item in its assigned place and keeping an adequate record thereof.*

The former of these laws indicates the fact that efficiency in production is promoted by having the right amount of the correct material available when and where it is needed.

In many firms, the saving accruing from the use of time and motion study and the latest and best machine tools is more than counter-balanced by losses in time and material, due to faulty stores organization or operation. The ideal condition would be that of receiving the material at the time when it is required for use, but as this is frequently impracticable,[2] some kind of reservoir must be provided where the material may lie until it is needed and from which it can then be withdrawn. This is particularly necessary in intermittent or semi-continuous processes where large quantities of components may be produced at regular or irregular intervals.

The first procedure is to make suitable arrangements for receiving and checking the goods, and then these must be sent to the storage place. Suitable facilities must also be available for handling and transporting material, and both its entry and its exit must be recorded so that a check may be kept on the quantity used or available at any given time.

[1]Loc. cit., p. 408.

[2]The receipt of material as and when it is required for manufacture is now practised by several American firms.

Receiving Materials.[1]

The Receiving Department is the point at which the material passes from the hands of the consignor or carrier into those of the manufacturer. It is necessary at this stage, therefore, to ensure that—

1. An order has been issued to cover the consignment.
2. The goods are of the kind, quality, and quantity specified in the purchasing order or receiving note.
3. The various departments interested are notified of the arrival of the goods.
4. Proper steps are taken to return unsuitable material or to lay claims for damage or loss.
5. Proper steps are taken to replace goods damaged or spoiled in manufacturing processes.

A carbon copy of each order (not necessarily including the price) should be sent to the receiving clerk and filed, preferably in alphabetical order, so that the goods may be checked on arrival. When it is impracticable to examine the material thoroughly at that time, the consignment should be accepted, subject to checking and correction. Prompt identification is advisable, to avoid delay in distributing material to the stores and in passing the invoice.

Checking of quantities by count or weight is a simple operation. The only point to be noted is the need for accuracy and thoroughness. But inspection of quality has varying degrees of difficulty. This is frequently performed by the Inspection Department, but in some cases a visual examination for obvious flaws or breakages is made by the receiving clerks. Some firms place all material received into a "bond" from which it is not allowed to be removed until the material has been released by the inspectors. This release is indicated by impressing a stamp on the receiving note, stating the number passed, rejected, and held for rectification. The material passed is stamped, or otherwise marked, by the inspector, and that rejected is indicated by a different mark, so that it cannot subsequently be returned in another shipment. Sometimes the rejected material is defaced or damaged to prevent this happening, but, in any case, the stamp or mark should be of such a kind that it cannot easily be erased. With quantity production particularly, it is frequently difficult to sort out material which is unsuitable and which,

[1]Some of the matter in this paragraph and those following has been taken from the report of the National Electric Light Association, Publication No. 2417.

through neglect of these precautions, has been transferred to the stores. In the case of defects that are not necessarily fatal but entail special care, arrangements may be made to perform rectification processes before the material enters the production line. Such articles must be marked to indicate this fact, and a definite procedure must be laid down for the purpose.

When similar articles are received from more than one supplier, it is advisable to use identification marks, so that in case faults are subsequently discovered in machining or other processes, the material may be returned to the original supplier. Marks of this kind should be impressed on a surface that is not to be machined, as otherwise they will be removed before the article is completed. If the part is machined all over, the mark should be transferred by the inspectors between the machining operations concerned, so that the stamp is never effaced. This procedure was found to be useful in drop forging and similar work where heat treatment was necessary. Samples of the steel were taken from the receiving bond, analysed, heat treated and tested both mechanically and microscopically before the material was released. A card, giving the correct method of heat treatment, was then issued. A system of numbering was also used to indicate the origin and nature of the steel. Thus, B B 5 2 represented a steel supplied by Brown & Bayley, the numeral 5 indicated that the steel was of the oil hardening variety and the numeral 2 showed the heat treatment required. Thus, when the forgings arrived at the hardening shop, the card B B 5 2 was referred to, and all the necessary instructions were obtained automatically. This symbol was also useful when breakages or other failures were returned from the customer. It may be supplemented in some cases by a system of painting in which the colour indicates the nature of the material.

Some firms use outside inspectors to check and pass material before it leaves the suppliers' Works, and in such cases, the inspector's stamp is an indication that the goods are of the required quality. Other aspects of this question will be considered in the chapter on Inspection.

The inspection procedure, at this stage, should be indicated by the specification in more or less detail, as outlined in Chapter II, and when a consignment of material arrives the Inspection Department should be notified immediately. If lots are received by the carload, it may be possible to inspect the material before unloading, thus saving considerable time and money in case of

rejection. The number of rejections of material received from each supplier is a good indication to the purchasing department of reliability on the part of the vendors, and is a useful guide when placing orders. The reliable vendor has little to fear from systematic inspection, and its moral effect on others is obvious.[1]

When the material is passed as fit for use, a record must be sent with the goods to the stores, so that a correct entry may be made in the stores ledger or stock records. The Invoice Department must be notified so that the invoice may be passed for payment. The Purchasing or Traffic Department must also be advised, so that tracing or pressing for delivery may be discontinued. These advices may be made in triplicate on the same form.

The carrier is responsible for loss due to non-delivery of part of a consignment, and the particulars should be noted on the receipt by the receiving clerk, so that they may be readily available when the claim is made. Claims for damage should be handled in a similar way.

Storing Material.

The form and the location of the stores vary with the nature of the material which is to be handled. This may be classified generally into—

(*a*) Raw material.
(*b*) Partly-finished material.
(*c*) Finished material ready for assembly.
(*d*) Finished material ready for shipment.
(*e*) Supplies.

These terms are relative and the classes overlap to some extent, as, strictly speaking, all material that enters the factory is raw material for that particular industry. However, partly-finished material usually comprises those articles that have had some work done upon them and are stored until required for further processing. Supplies include facilities for manufacture, such as oil, files, waste, etc., which are used in definite quantities but do not enter into the finished product.

According to the Second Law of Material Control, all material must be stored in a safe and convenient place in a systematic manner, but the *degree* of safety or convenience depends on circumstances. Large castings or steel billets may safely be

[1]It may be convenient and economical for a supplier to keep a repair man at the receiving end to make minor adjustments. In other instances, the man may divide his time between several purchasers.

stored in piles in the yard, as they are too bulky and heavy for pilfering, but small and portable articles must be kept under lock and key. The storekeeper can be held responsible for the material in his charge only if he is given authority to exclude from the stores all persons who are not employed there, or whose business does not necessitate their entrance. Questions of transport, also, will be more important in the former case than they are in the latter. Perishable materials sometimes require special arrangements for control of temperature or humidity. Fire risk is always present with inflammable materials and may determine the location of the stores.

In general, the storeroom should be located centrally with reference to the producing departments, but this does not necessarily imply the existence of one central storeroom. Each manufacturing department usually has its own stores to minimize costs of handling and transport, but these may be supplemented by a central storeroom in some instances. Whatever arrangement is adopted, however, it is advisable to have centralized control of the stores, so that a unified policy may be used. This sometimes necessitates a separate department under the control of the production manager, and at other times, the stores may be subordinate to the Purchasing Department.

Quantities and Arrangement.

The arrangement of the stores depends on the nature and quantity of the material to be stored, and varies in different kinds of business, but there are a few considerations that apply generally.

It is difficult to anticipate the needs of many factories, particularly in the case of industries subject to seasonal demands, such as those allied to the building trades. The storage of large quantities enables savings to be made in purchasing, but increases the amount of capital tied up in materials, land, buildings, and equipment. There is also the danger of spoilage or obsolescence if the demand is small as compared with the supply. On the other hand, small quantities are liable to cause inconvenience and loss when unusual demands occur or when new consignments are delayed. These considerations determine the maximum and the minimum quantities that must be kept in stock, and it is the storekeeper's business to see that the stock on hand does not rise above the one or fall below the other. The minimum quantity may be calculated as a definite percentage of

the probable orders containing the part in question. This is expressed as so many days' supply, and is based on the estimated time of replacement. Thus, with material that takes a long time to obtain, the percentage or number of days' supply kept on hand must be correspondingly large. Between these two limits lies the "ordering point" or "normal stock" at which point replenishments should be ordered. Shortage reports are sometimes sent periodically to the Purchasing Department as an indication that more material is needed.

Both the ordering point and the minimum stock will vary somewhat with business conditions. When business is brisk, not only does the rate of consumption increase but, as supplying firms and transport agencies are also busy, the time of replacement is likely to increase. Another contributory factor is the amount of storage space available and the relative cost of increased storage facilities and inventories must be balanced against the risk of interruptions in the productive programme if more storage space is not provided.

In quantity production work, the material required may be estimated from the production orders and bills of material, but repairs and other emergency jobs must be handled specially. The stores system must be sufficiently flexible to take care of these cases. Supplies may be handled by issuing definite amounts at specified times according to the amount of work that is being done, extra quantities being issued only by means of a special order from the foreman.

Handling.[1]

The stores should be arranged in such a way that material can be located easily, and that handling difficulties are reduced to a minimum. The cost of handling evidently varies with the product of size (or weight) and distance. The path of the principal materials or groups of materials may be laid out in the form of lines on a plan of the stores or factory, the thickness of the lines or bands being proportional to the quantity handled. In this way, long and heavy transportation routes may be reduced and the most economical arrangement determined. In any event, it is desirable that materials most in demand shall be near the point of issue. Suitable racks for bar material and bins for small parts, should be provided. Steel racks or bins are

[1]This subject is described in detail in *Mechanical Handling and Storing of Materials*, by G. F. Zimmer (Fourth Edition), 1932; and *Materials-Handling Equipment*, by M. W. Potts (Pitman), 1946.

more expensive than wooden ones, but they are more durable, occupy less space, and have a lower fire risk.

The Ferguson Company (Cleveland) has designed a circular warehouse which can be built a segment at a time, permitting expansion without any loss of efficiency. Trains and trucks unload on the outside of the circle and trucks pick up outgoing loads in the centre. Fork trucks load goods into trailers, and these are drawn by tractors to the shipping dock in the centre, thus expediting handling and reducing costs.

Considerable savings have been effected by the use of standard packages and containers, as the following examples show.[1]

> . . . In moving one particular commodity, it was computed that scientific packaging and stowing would enable four freight cars to do the work of five under the present system of packaging and stowing. Twenty per cent less equipment is required to handle the same "pay load" and incidentally a very substantial reduction in loss and damage claims is indicated. . . . A manufacturer, who used large quantities of a certain material, felt that the shipping boxes were much too strong and heavy, and hence were costing him too much in freight. The primary attack was successful in saving freight charges of $54,000 per year. These boxes, containing from 500 to 800 lb., were lifted from freight cars by a travelling crane and stacked in tiers to a height of about 30 ft. The manufacturer made the statement that savings which were effected, due to the lighter packages, were almost as much in crane-handling costs for vertical transportation, as the savings in freight charges for horizontal transportation. . . . In New York City the average driver of a milk wagon lifts 25,000 pounds of glass bottles, milk, and wooden carrying trays per week. A revolutionary change in container design cuts his burden to 10,000 pounds per week. Yet the prices paid to dairy farmers are the same; earnings of milk-wagon drivers are increased; and the householder pays for his *milk 1½ cents less per quart.*

Adequate passages or gangways must be provided, and in most cases it is necessary to make them sufficiently wide for two trucks to pass or for one truck to turn. Systematic arrangement and suitable labelling of bins are necessary, so that material may be located easily and quickly. The arrangement must allow sufficient room for normal expansion.

The handling of material by mechanical means has increased rapidly within the last few years[2]. Overhead cranes (Fig. X.1.) and conveyors (Figs. X.2., X.3.) have been used for heavy and bulky materials for many years, but now systematic studies are

[1] "War on Weight," Walsh, *Mechanical Engineering,* February, 1940.
[2] See *Mechanical Engineering,* September, 1941, p. 649.

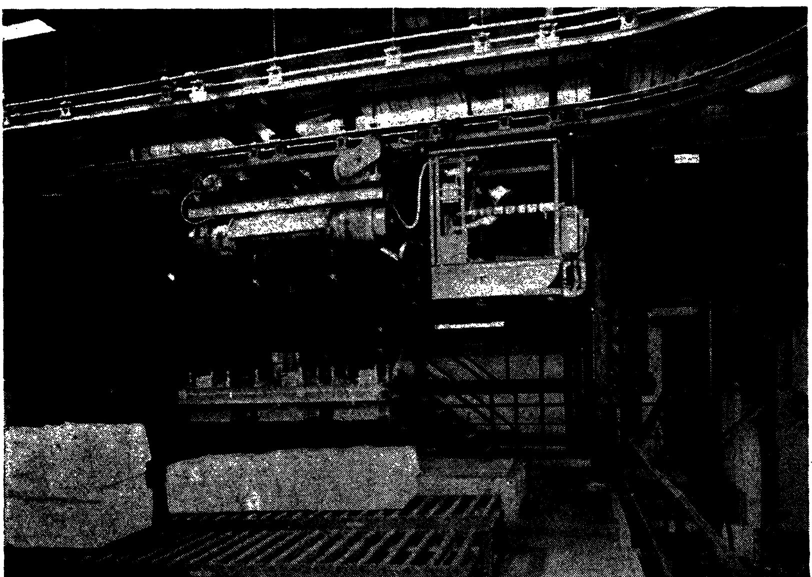
made so that handling costs may be reduced to a minimum. Gravity conveyors, rollers, and belts (Fig. X.4, X.5.) are employed in many light industries for transporting articles from the top to the bottom of the factory and from one process to the next. Bucket conveyors or belts are used for carrying large quantities of coal or sand in the power house or the foundry (Fig. X.6.). Magnets and air hoists are employed for lifting purposes. The electric truck has become almost indispensable for horizontal transport from one shop or department to another. Mechanical unloaders and pilers (Figs. X.7., 8., and 9.) are used for the purposes indicated, and moving chains are employed for transportation and assembly purposes in the automobile and other similar industries (Fig. X.10.). It is not the purpose of this book to describe these facilities in detail, but the above gives some indication of their nature. It is intended to emphasize the considerable savings that result from their use not only in the stores, but in most parts of the factory.

(Courtesy of Chain Belt Co. of Milwaukee)

Fig. X.I. Unloading Coal From Railway Trucks by Overhead Crane and Delivering on to Belt Conveyor

(*Courtesy of* Canadian Machinery *and Cleveland Crane and Engineering Co.*)

FIG. X.2. GRAB WITH MOTOR OPERATED SCREWS FOR PICKING UP BALES

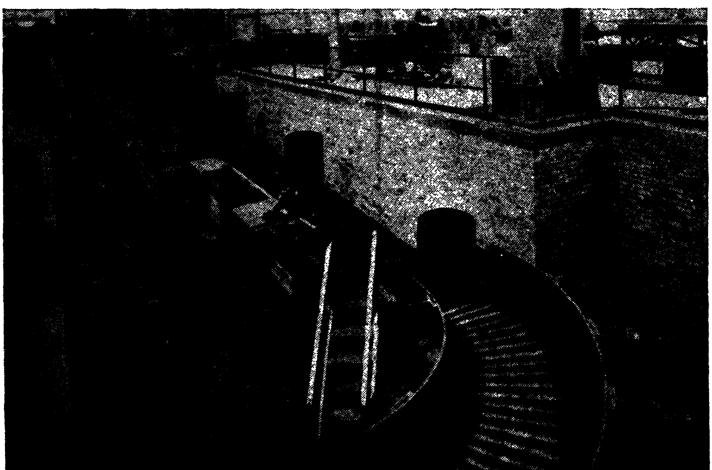


(*Courtesy of* Canadian Machinery *and Cleveland Crane and Engineering Company*)

FIG. X.3. MONORAIL CARRIER HAS JUST RELEASED THREE BAILS OF PAPER PULP BY REVERSING SCREWS IN GRABS AS IN X.2

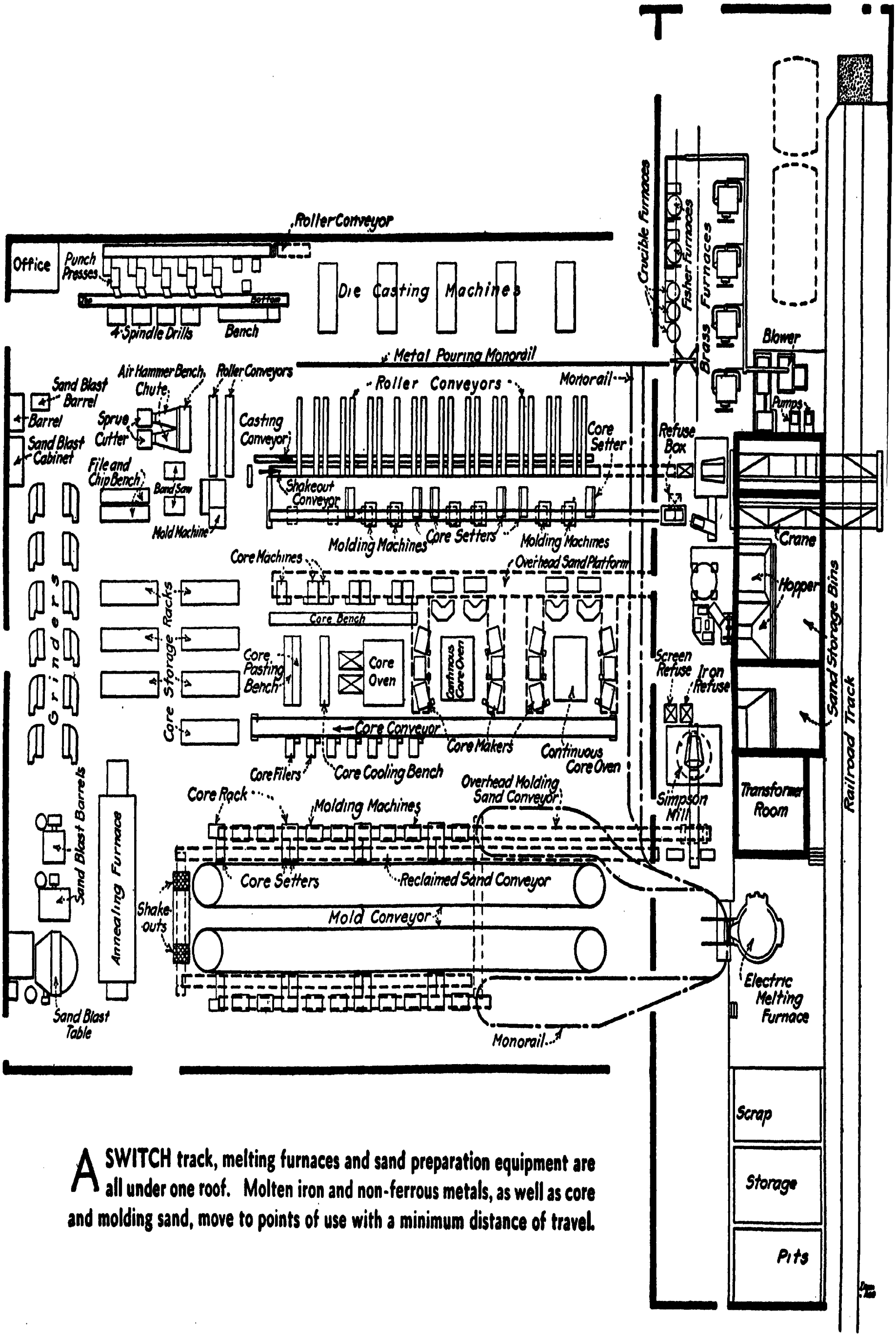
(*Courtesy of Riley Engineering and Supply Co., Toronto*)

FIG. X.4. SPIRAL CHUTES DISCHARGING BAKERY GOODS ON TO A BELT CONVEYOR



(*Courtesy of* Canadian Machinery)

FIG. X.5. COOLING CONVEYOR FOR COILED STRIP AT STEEL COMPANY OF CANADA

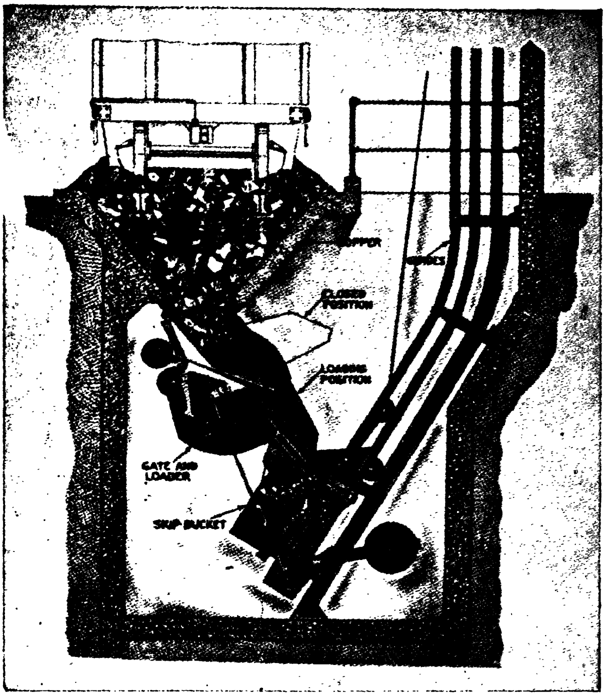


A SWITCH track, melting furnaces and sand preparation equipment are all under one roof. Molten iron and non-ferrous metals, as well as core and molding sand, move to points of use with a minimum distance of travel.

FIG. X.6. ARRANGEMENT OF FOUNDRY WITH CONVEYORS

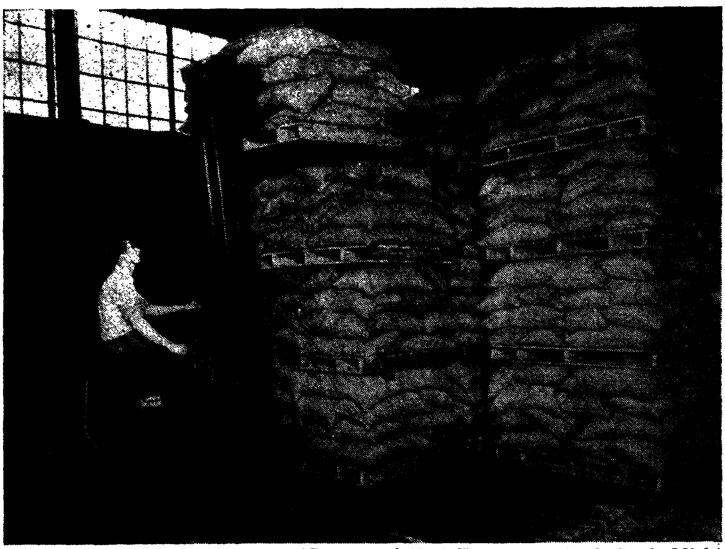
Reprinted from *The Iron Age*, 16th April, 1931

(*Courtesy of Link-Belt Co., Toronto*)



(*Courtesy of Link-Belt Co., Toronto*)

FIG. X.7. WEIGHT-OF-MATERIAL-IN-BUCKET AUTOMATIC LOADER

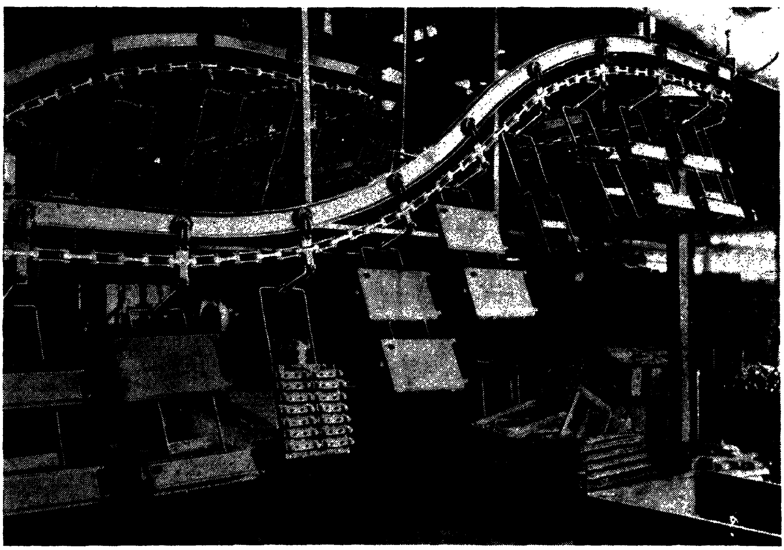


(*Courtesy of Clark Tructractor, Battle Creek, Mich.*)

FIG. X.8. CLARK CARLOADER CODE "STACK" HANDLING BAGS OF AMMONIUM SULPHITE ON PALLETS AT VISKING CORP., CHICAGO, ILLINOIS

(*Courtesy of Clark Tructractor, Battle Creek, Mich.*)

FIG. X.9. PORTABLE BELT CONVEYOR



(*Courtesy of Link-Belt Co., Toronto and* Canadian Machinery)

FIG. X.10. MONORAIL CONVEYOR FOR HANDLING STOVE PARTS

Potts gives the following general rules for materials handling equipment—

1. Conveyors are generally used to move goods *continuously* from one fixed spot to another. This implies a definite line of flow and rigidity of arrangement. It may also be remarked that the conveyor itself is part of the storage space and so saves a certain proportion of the floor space. The speed of all manufacturing operations is thus controlled by the speed and capacity of the conveyor system.

2. Cranes and hoists are employed to move goods *intermittently* over an area of fixed limits.

3. Mobile trucks or tractor trains are used to move goods *intermittently* between many points without regard to fixed limits. Pallets are frequently employed for convenience in handling the goods in large piles and for arranging them in the storage space. (Fig. X.8.)

Classification.

Stores represent money sometimes as much as 25 to 50 per cent of the capitalized value of the business—so that inventory losses or poor material control may have serious results. They should be handled with the same care and precision as other parts of the company's finances. This process is facilitated by dividing the stock into classes under a scheme best suited to the needs of the factory. These classes form a basis for the study of investment and turnover which enables those interested to follow the stock very closely by means of monthly reports.

Turnover is computed in terms of the average stock on hand during a given period divided into the total issues for the same period. Spare parts and other slow-moving items of stock should be segregated into classes for separate study. Methods of classification are divided by the National Electric Light Association[1] into four types, namely—

1. Classification by nature of material alone.

2. Classification by property accounts primarily, and by nature of material secondarily.

3. Classification by company departments primarily, and by nature of material secondarily.

4. Classification by location primarily, and by nature of material secondarily.

The second type indicates the use to which the material is to be put. The fourth applies to companies operating over a wide area, and shows the investment in each division.

[1]Loc. cit., p. 13.

Basset and Heywood[1] describe three methods of classification—

(*a*) By part, number or type, where materials are stored in numerical order.
(*b*) By grouping similar materials or parts together.
(*c*) By grouping together all parts that will ultimately be assembled together.

Methods (*a*) and (*b*) have the advantage that standard parts, which enter into a number of different assemblies, can easily be found, but method (*c*) gives greater convenience when articles are being withdrawn for assembly purposes. No single method is applicable to all cases, but the classification chosen must be that best suited to the industry under consideration.

Records.

Accurate stock records are indispensable to good storekeeping. Poor records breed careless buying and poor service, and introduce an element of guesswork that should not exist. The records should be kept in the Stores Department general office where they would be accessible at all times for reference and study. The following, by Basset and Heywood, are some of the advantages claimed for a good system of stock records—

1. No material is likely to be used for other than business purposes.
2. Production delays, due to lack of material, are avoided.
3. Overbuying and "freezing" of capital are prevented.
4. All material can be accounted for in the finished product.
5. The taking of inventories is facilitated.
6. Less time is lost in searching for material.

The stores ledger may be kept either in card or loose-leaf form. It records all material received and issued together with orders placed for the particular part under review. In some cases, also, the amount of material assigned or earmarked for particular jobs is recorded. From this ledger, the amount of material on hand can readily be computed, and compared at intervals with that actually in the bins. In this way, a continuous inventory may be kept, the reliability of which will depend on the accuracy of the posting.

When material is issued, it is important that, whenever possible, a definite job number, to which its value can be debited, should be given. Otherwise it is difficult to ascertain accurately the cost of material for any order, and the total amount to be divided up as "expense" will be unnecessarily large. Methods of

[1]*Production Engineering and Cost Keeping*, p. 24.

pricing materials for this purpose vary with different firms. Some base their prices on weighted averages, some on separate lot prices, and others on latest invoice prices. Some firms add transportation charges to the cost of material, and others use different methods for dealing with these items.

The accuracy of the records should be checked by inventory or stocktaking at least once a year, more often if necessary. The *perpetual inventory*, mentioned above, is taken by comparing a small number of items with the stock records and then proceeding *seriatim* with the others. The *periodic inventory* covers the whole of the stock at a definite time. It compares the values of the actual material present at that time in the storerooms with the figures given in the general books. It is really an auditing process, and is intended to indicate any discrepancies between the books and the facts. If such differences are constantly occurring in certain classes of material, special attention is directed to these points.

A master record is desirable to give information to people within the organization who are not familiar with the arrangement of the separate stores. This should include "Re-sale or Service" stores.

Stores Economy.

Reclamation of scrap and the prevention of waste in supplies are frequently important parts of stores economy, and many firms are now paying particular attention to these items. In some instances, it is impossible to issue the exact amount of material necessary for a particular job. The issue should then be marked or indicated in the records so that worthwhile quantities of unused material will be returned and credited to the job, otherwise material costs will be excessive. Another factor is the prompt return of containers for which credit may be obtained from the vendors. A considerable amount of money may be tied up in this way if the stores system does not ensure the prompt return of these containers to the suppliers and their protection from loss or damage. If containers are not already marked with the owner's name, some system of identification should be employed.

Losses due to obsolescence and spoilage can only be minimized by the store's keeping in touch with the departments for whom the material is bought. When new developments are of constant occurrence, a continual scrutiny must be made of ma-

terials that are moving too slowly or not at all. This is indicated by the "turnover ratio" which shows the average time that material remains in stock. Thus, a ratio of four means that the material in question remains in the stores for an average period of three months. The storekeeper must see, as far as possible, that all of the old material is used before the new is issued. When material has become obsolete, authority must be given for its disposal. In this connection, a salvage man, or a department, is frequently able to effect considerable savings. Such material, though still in good condition, should not be carried in the books at its original value if it is not saleable by reason of obsolescence, inadequacy, or because there is no longer a demand for it.

New forms of protective packaging were developed and widely used in World War II to avoid losses caused by damage or corrosion.

These methods may be classified[1] as—

1. Corrosion preventive compounds having a consistency ranging from that of a light oil to that of a heavy grease or asphalt paint. This was covered with a grease proof, acid free wrapping material.

2. Waterproof protection, consisting of a water resistant wrap for more effective protection against liquid water. It was generally, but not invariably, used in addition to (1).

3. Moisture-vapourproof protection obtained by incorporating a drying agent in the package, combined with a vapour-proof barrier. An atmosphere of low relative humidity was thus maintained inside the package. Metal foil and plastic film barriers were frequently used.

4. Special sealed shipping containers were designed to reduce damage due to rough usage or improper handling.

[1]*General Electric Review*, December, 1945.

CHAPTER XI

ARRANGEMENTS FOR MANUFACTURE AND ASSEMBLY

General.

The cost of manufacture for any material depends upon a variety of factors. The location of the plant, arrangement of machinery, and floor space, methods of fabrication, lighting, heating, ventilating, and methods of remunerating labour all have a considerable bearing on this cost. The influence of quantity, or mass production, has already been discussed in Chapter I and is summarized by Alford[1] in the following laws—

1. *Larger scale production tends to increase operating efficiency and competitive power.*

2. *In large-scale production the unit time of production tends to approach the actual operating time as a limit.*

Questions of shop transport and layout also have to be considered in the light of the law of Flow of Work[2]—

3. *The greatest economy in progressing materials through a manufacturing plant is secured when the materials move a minimum distance in passing from operation to operation.*

Interruptions in the production programme are expensive, and must be reduced to a minimum by good plant maintenance and prevention of breakdowns in machinery.

The influence of lot sizes and the provision of suitable facilities in the form of jigs and tools are also considered at this point, but the measurement of the time taken by various operations and its application to production will be described in the following chapter.

The principal object is to ensure that machines and operators are kept going at their maximum productive capacities on suitable work, as an idle or lightly-loaded unit represents loss of money.

Throughout this chapter, it will be assumed that there are sufficient orders in sight to absorb the productive capacity of the plant, but it is realized that it may be necessary in slack times to produce work for stock, or to produce and sell at cost or at a slight loss in order to keep the men and machinery employed.

[1]Loc. cit., p. 407.
[2]Ibid, p. 415.

Costs do not stop when the works are not running, and the loss on sales made under these conditions may be less than that incurred by shutting down the plant. In addition to this, there is the loss involved when skilled workmen obtain other employment and have to be replaced by raw hands when the plant is re-started.

Plant Location.

The principal questions that arise in connection with plant location are those of *transportation*, *labour*, and *power*. There are also a number of subsidiary factors that will be considered as they arise.

Transportation facilities are of primary importance because material must be brought to the plant, and the finished products removed from it rapidly and economically. Where heavy or bulky materials are involved, the cost of transport to the plant is frequently the paramount issue, and the factory must be located near to the source of supply of its raw material. In other instances, where the cost of transport is relatively small, nearness to the principal market may be the factor that determines the choice of site. Many factories, such as electrochemical plants, are located near water-power plants where there is a plentiful and cheap supply of electrical energy, while others, such as the steel industries, require large quantities of cheap fuel, and accordingly are placed in the vicinity of the coal fields. The relative cost of transporting raw materials, and of producing or transmitting the power required by the factory, has a considerable influence on the choice of locality. The industries of certain districts, such as the steel plants of Pittsburgh and Sheffield (Eng.), have been due to natural conditions, but the location of others, such as the automobile factories of Coventry (Eng.) and Detroit, the tire industries of Akron (Ohio) and the furniture plants of Grand Rapids, appears to have been caused by no particular reasons save the success of the first plants operated there. Such *specialized* centres or communities have a local prestige and a plentiful supply of labour that is trained in the particular class of work in which the centre specializes.[1] They are also able to attract capital, to make suitable financial arrangements, and to keep in touch with the latest technical developments in their particular branch of industry. Trading conditions are usually better because both buyers and sellers tend to

[1]See reasons for locating "Wright Aeronautical Plant in Cincinnati," *Mechanical Engineering*, October, 1941.

concentrate in that locality, and repair shops and subsidiary component factories are also likely to be established there. As against this, there is a decentralizing tendency in which branch factories are established near the various markets; this is particularly notable in countries such as Canada, where the large centres of population are far apart and the intervening districts are sparsely populated. It is stated[1] that the General Electric Company (U.S.A.) is spending more than $100 million on its decentralizing programme. In 1946, the number of plants operated was three times that in 1945. It is realized that it is bad for the local community to be tied too closely to a single company, and therefore the policy is to decentralize if the G.E. employees in a city constitute more than 25 per cent of the local work force. It is claimed also that this policy develops managerial ability in the lower ranks, permits production nearer to the market and creates closer ties between management and workers. Some industries, such as laundries, bakeries, refrigeration plants, etc., are purely local in operation and must necessarily be placed near their market.

Climate is sometimes an important factor, as unusual conditions of temperature or humidity may seriously affect the efficiency or health of the workers, or may determine the type of labour that must be employed. The *water supply*, either for consumption or process work, must be carefully considered. This may be obtained from the district water supply, from wells or reservoirs. The amount available is frequently important, as in the case of a steam-power plant, which requires large quantities of cold water for condensing purposes. The quality of the water, and its freedom from dissolved solids, may also determine its suitability for industrial use. The *disposal of waste* is another factor that may be of importance. Large quantities of ash are produced by steam-power plants, and must be removed. The effluent water from some gas plants or chemical processes is frequently unsuitable for running into a sewer or stream, and odours or gases may prevent the choice of a site in populous centres. Provincial, state or municipal *legislation*, such as those relating to hours, wages, liability, smoke emission, and other similar enactments, may have a modifying influence on some of the other factors mentioned above.

The question of locating an industry in or near to a city, or in a rural district, is one that requires careful consideration. The

[1] *Modern Industry*, December 15, 1946.

cost of land and the taxes levied on land and buildings are usually greater in a city than they are in the country, and the cost of labour, both for erecting and running the plant, is likely to be more because the cost of living is higher. The city plant has the advantages of protection from fire and burglary, and of the use of municipal streets, sewers, and other facilities. The country plant has the advantages of relative freedom from restrictions (such as smoke and nuisance laws) and of freedom for expansion. Also, these communities sometimes offer taxation rebates or free land, as inducements for firms to locate there.

The cities have an abundant supply of labour, and are able to offer educational and amusement facilities, but industrial unrest is usually more prevalent in large centres than in small ones and is liable to offset these advantages to some extent. Many large firms, which are not dependent to a great extent on other industries, have built factories in rural districts and have provided model villages and local amusements to solve the housing problem. Examples of this are to be found at Port Sunlight and Bournville, in England. Such schemes are good, but welfare work of this kind is no substitute for wages, nor must it be used as an excuse for offering less than the standard rate. In rural districts, continuity of employment is very important, and for this reason, seasonal industries should be located in or near large centres of population.

In some industries the "degree of accessibility" of the site is important, as this may control the living conditions. If domestic supplies or housing materials must be transported over long distances, the cost of living is high and correspondingly high wages must be paid, thus increasing the manufacturing cost of the product.

Gutteridge[1] gives the following two examples of factors influencing the location of industries—

The case of a Portland cement works on the Great Lakes in the U.S.A. exemplifies the position of the works in relation to the quarry and the market. In the manufacture of Portland cement, the relative proportions by weight of the materials are approximately limestone 4.3, clay 1.7, coal 1.0, and finished product 3.5. The alternatives in this case were placing the works at the limestone quarry or at the market, a distance of four hundred miles across the lakes from the quarry. In the first case, the cost of transport of the principal raw materials would be saved and, because the weight of the raw material is reduced in the kiln by about 50 per cent, only the actual finished

[1] "Factory Planning," *Engineering*, 11th January, 1935.

product would have to be carried. In the second case, the finished cement would be fresher and could be loaded on to motor lorries which could deliver direct to the consumer without any further re-handling. The clay and coal could be obtained locally, and the electricity charges would be considerably lower than at the quarry site. By the provision of specially constructed steamers with automatic loading and discharging equipment, handling charges would be a minimum. In this case the site chosen was at the market.

Another case of choice of site is that of a large power station on an important river in England, where the alternatives were whether to erect the power-station down-river well away from the city and transmit the current to the city by underground or overhead wires, or to build it in the heart of the city and bring the coal by steamer and remove the ashes by barge on the river. By having the power house in the city at the centre of its market, the cost of twenty miles or so of transmission lines and their heavy way-leave charges, together with electrical transmission losses, would be saved but, because of its position in a residential neighbourhood, an additional capital sum of $1,000,000.00 would have to be expended on plant for cleansing the smoke stack gases. The choice in that case was a site in the city.

The Studebaker aviation engine plant (1941) was divided into three factories at Chicago, Fort Wayne and South Bend, respectively. After a careful survey by the Industrial Relations Division, it was found that the 14,000 men required could not be obtained from South Bend alone and that the housing problem created there would be insoluble. Accordingly, precision parts were made in the Chicago factory, gears and other parts at Fort Wayne and assembly at South Bend.

The Wright aeronautical plant was located in Cincinnati[1] because it offered a background of three or more generations in the machine tool industry and therefore this location contained an abundant supply of trainable material—men who had inherited a background of mechanical aptitude and manual dexterity, so necessary in a machine operator. A suitable training programme was established to provide a pool of potential operators.

Anderson[2] describes the Central Manufacturing District of Chicago, which is a privately-operated industrial community near the geographic centre of Chicago. It has special terminal and transport arrangements, is close to a large supply of labour, and is scientifically planned and centrally heated. Club, restaurant, and banking facilities are provided, and low insurance rates are prevalent on account of the nature and arrangement of the buildings and the protection furnished. Other cities

[1] *Mechanical Engineering*, October, 1941, p. 697.
[2] *Industrial Engineering and Management*, p. 88.

have zoning laws by which certain districts are segregated for manufacturing purposes. Many industries are now located in the suburbs of large cities; this is a compromise between city and rural location, and partakes of the advantages and disadvantages of both.[1]

The actual site chosen and the amount of preparation required depend on the nature of the industry and the kind of building to be erected. Expert advice is available on this subject, and each factory must be treated as an individual case. In some instances, the ground must be levelled, and in others, a sloping site is advantageous because it allows the use of gravity for transporting material from one process to the next, or because it permits material to enter the plant at several different levels.

An analysis of the motives that led to the choice of sites in 332 new factories (England) in 1933 is as follows—

> . . . in 90 convenience of premises was the motive; 65 were chiefly influenced by the proximity to other factories in the same industry; 47 by branch factories; 35 by accessibility of raw materials; 35 by proximity to markets; 23 by suitability of labour; 14 by cheap land, low rent or low rates; and the remainder for various reasons.

Size.

The size of the factory or business has an important bearing on the question of location; a large business tends to transform the surrounding district, while a small one is made or marred by it. There is an optimum size for each trade and for each set of conditions, and the net output per person is some guide in this connection. The following figures are taken from the Final Report of the Fourth Census of Production (England), 1930—

> In this report it will be found that, in the firms building motor-cars or bicycles on mass production lines, the highest net output of £257 per person is found in the 29 firms employing 1500 or more persons. The lowest output of £188 per person in this industry is recorded in the 228 firms who employ between 11 and 24 persons. In shipbuilding, the highest net output of £246 per person is found in those firms employing between 200 and 299 persons, while the lowest of £170 per person is realized by the 86 firms employing between 11 and 24 men. In the electrical trade, the 24 largest firms employing 1500 or more persons produce the best result of £246 per person; the worst being the 10 firms employing between 400 and 499 persons, £186 per person. In the aircraft industry, the highest net output per person of £321 is produced by the 5 firms who employ 25 to 49 persons, the next highest

[1]See also "Industrial Zoning," by Hugh Beaver, *Engineering Journal,* August, 1937.

being the 8 firms who employ between 750 and 999 persons, with a value per person of £283.

An analysis given by Weart[1] of the distribution of 228 plants moving from one city to another (U.S.A.) in 1927, indicates a decided tendency to leave the very large cities and to settle in communities having a population of 10,000 to 200,000. Many executives of large firms visualize the decentralization of manufacturing facilities in a number of medium-sized units with co-ordination and general control of the whole.

The following excerpt from a paper by Alford and Hannum[2] compares the results obtained by small and large units in various industries—

The opinion is frequently expressed that there is a most favorable, or optimum, size of manufacturing plant to produce any particular article or commodity. Our first study indicated that in many industries the smallest plant investigated had a higher rate of production than those that were larger. To quote—

> The smallest company has a higher rate of production than the largest in 35 industries.
>
> The smallest company has a lower rate of production than the largest in 18 industries.
>
> The smallest company has the highest rate of production in 16 industries, and a high rate in 5 industries.
>
> The smallest company has the lowest rate of production in 6 industries, and a low rate in 16 industries.

These comparisons indicate that the optimum size of plant from the productivity viewpoint may not be the largest.

In the second study, the optimum range of size of plant, expressed in kilo man hours worked per year, was determined for each of the four industries. The figures, which indicate quite small plants and support the theory of decentralization of industry, are—

Industry	*Optimum kmh. per year*
Blast-furnace operation	270–640
Machine-tool building	30–80
Petroleum refining	40–140
Lumber manufacturing	50–300

The kilo-man-hour capacity of the plants operating within these optimum ranges is a comparatively small part of the total kmh. capacity of each industry. The percentages are: in blast-furnace operation, 33.8 per cent; in machine-tool building, 4.5 per cent; in petroleum refining, 7.7 per cent; in lumber manufacturing, 15.2 per cent.

[1] *Engineering*, 10th August, 1934.
[2] *Mechanical Engineering*, December, 1932.

Form of Building.

The kind of building erected on the site depends largely on the nature of the processes that are to be accommodated and the amount of capital available for building it. A careful survey must first be made of the manufacturing operations required and the amount of floor space necessary. Idle space for gangways, shop storage, stairways, elevators, columns, and similar purposes must then be added to give the gross floor area, and this involves a decision as to the number of storeys over which this area is to be distributed.

The present tendency, where circumstances make it possible, is to use *single storey* buildings for heavy work. These have the advantages of better visibility (generally), relative freedom from vibration troubles, better crane facilities, lower operating costs, greater net floor area, less fire hazard, higher permissible floor loads, and greater flexibility for routing and expansion. On the other hand, the *multi-storey* building occupies less land and costs less for roofing and foundations, although it is frequently more expensive, when calculated on a net area basis, because of the cost of stairways, elevator service, etc. It also has the advantage of allowing the use of gravity conveyors for transport purposes, and so is often preferred for light articles such as foodstuffs, tobacco, and similar products. The assembly of small, compact units is also usually facilitated by this arrangement. Combinations of single and multi-storey buildings may be used advantageously in some industries.

The form of the building will depend upon the site and the nature and sequence of the manufacturing operations, and it will usually be a compromise between what is desirable from the architectural and manufacturing standpoint, and what the owner can afford to pay. Some shops need practically no machinery, others are filled with machinery and have very little hand work. Some are equipped with extensive conveying and mechanical handling devices, others have very few. All of these factors will influence the form and construction of the building. The form and equipment of the building must be such as will reduce fire hazard to a minimum. It is estimated that the average fire loss in the United States is $450,000,000 per annum[1] and adequate protection, both for persons and records, is an obvious necessity.[2] Safe, fireproof construction should be used

[1] *Journal of Franklin Institute*, January, 1937.

[2] The fire loss in Canada for 1943 was $31,464,710 and in the previous ten years was $256,911,711. *Monetary Times*, October, 1944.

as far as possible, and automatic sprinklers should also be provided. Processes and materials that involve fire or explosion hazard should be segregated and carefully supervised.

Adequate protection must be provided for records and drawings, as these may be very difficult and, in some cases, impossible to replace. This matter has been examined in detail by the National Fire Protection Association[1] (U.S.A.) and records have been divided by them into four classes—

CLASS 1. "*Vital*, underlying the organization of an establishment and those giving direct evidence of legal status, ownership, accounts receivable and incurred obligations." These should have the best protection possible by fireproof vaults or safes. Sometimes they should be duplicated and the two copies kept in different places.

CLASS 2. "*Important*, records that while not irreplaceable, can be reproduced from original sources only at considerable expense." The amount of protection provided depends on their degree of importance and local circumstances.

CLASS 3. "*Useful*, records, the loss of which would cause temporary inconvenience but otherwise would entail no serious permanent disadvantage." No special protection need be provided, but there should be a minimum of combustible surroundings.

CLASS 4. "*Non-essential*, records that have no present value and should be destroyed." No protection necessary, but undue accumulations should be destroyed.

The report states that the seriousness of water damage to records is often overrated and that most fire-resistive record containers afford considerable protection against serious water damage, but it is suggested that in any storey, records should be raised a few inches above the floor. Further details, including estimates of total combustible content and equivalent fire durations for various sets of conditions are given in the original report.

In some occupations, particularly those involving mental work the efficiency of the workers is reduced by *noises* emanating from the shops, offices, or street. Considerable attention has recently been directed to this subject and, if desired, sound insulation may be incorporated in the design of the building.

Other aspects of this question are to be found in standard

[1]See "Protection of Records," N.F.P.A., 60 Batterymarch St., Boston, Mass., 1935.

treatises on mill building construction, and to these the reader is referred.[1]

Power.

—Where machinery is used, mechanical power of some kind is necessary to drive it. This may take the form of direct driving through gears, shafts, or belts, operation by electric motor, water, or compressed air. The amount of power to be provided depends upon the constancy or the variability of the demand. Some machines, such as rolling mills, have an intermittent and widely-varying demand, while the power required by a machine tool working at a definite feed and speed is practically constant. The power requirement of a machine shop, therefore, can be estimated fairly closely from the figures, which are supplied by the makers, for each machine. To this must be added losses in transmission, which, with a belt drive, may be as much as 25 per cent of the power absorbed by the machine.

Additional power must be provided for service purposes, such as cooking, elevators and conveyors, and lighting.

A careful survey of the needs of the plant must be made in the first place, preferably by a consulting or other engineer who is experienced in this class of work, so that the cost of the power required may be reduced to a minimum. Calculations are made on the basis of (*a*) buying power from a central station, (*b*) producing power at the factory. The former case is fairly straightforward, as public utility or power companies will offer a contract specifying the cost of power supplied by them under the conditions obtaining in the factory. This service also has the advantage of reliability, as a total breakdown very seldom occurs in a large central station. There is the possibility, however, of breakdowns in the distribution lines if these are subject to high winds, ice deposits, or similar troubles. The distance of the factory from the generating station will be a factor in this connection.

Isolated factories frequently have their own power stations, operated by steam plants or by oil or gas power. The relative advantages of these depend on the distance and method of transporting the fuel, on regularity of supply and on the possibility of using the waste heat. Some industries require large supplies of steam at low pressures for process work. These may profitably produce power by using the steam engines or turbines

[1]See "Fire Protection of Factory Buildings," *Manufacturing and Industrial Engineering*, July, 1937.

as reducing valves, exhausting at a pressure of from 2 to 30 lb. per square inch for use in the manufacturing operations. In other cases, the exhaust steam, or some of it, is used for heating the buildings in winter, but then arises the problem of its disposal in summer time. The resulting losses may make the scheme uneconomical.

One central station[1] produces steam at a pressure of 1,350 lb. per square inch and then sells the exhaust steam at 180 lb. per square inch to a manufacturing company close by. If oil supplies are abundant and cheap, or gas is available as a by-product from a blast furnace or other plant, it may be economical to use internal combustion engines for producing power.

Some industries, notably the metallurgical and ceramic processes, require fuel for manufacturing purposes, and the waste heat is sometimes employed as a measure of economy.

Considerable attention has been paid during the last decade to the conservation of heat and to the elimination of waste generally, and this has been particularly evident in the generation of power. The relative advantages of water and fuel for this purpose are primarily matters of locality, and in some districts each is used to supplement the other.

As in the case of manufacturing operations, power generation becomes cheaper as its quantity is increased. This favours the large central power plant. But the other considerations noted above may work out in favour of a small private power plant. The reliability of the latter depends on the equipment of the plant, and on its supervision and maintenance, but the stand-by services of a central power station can be utilized if required—at a price.

Heating.

Loss of output, due to unsuitable or inefficient heating conditions, is not always realized, but is frequently very appreciable. It is not sufficient merely to supply the correct amount of heat. It must be properly distributed. Heat given to the ceiling is of little value as far as the workers are concerned; it must generally be distributed at or below the breathing line. The indoor temperature that should be maintained at this level depends on the nature of the manufacturing process that is being performed and on the amount of physical exertion involved. A temperature of 68° to 70° F. is usually maintained in offices and other places

[1]Deepwater Station, New Jersey, U.S.A. For details see *Power Plant Engineering*, 15th November, 1929, and *National Engineer*, April, 1930.

where the work is of a sedentary nature,[1] but in work-shops, temperatures of from 55° to 65° F. are usual.[2] Paint shops and other special departments require temperatures of 75° to 80° F. These temperatures are modified to some extent by the relative humidity of the air in the building. The *amount* of heat to be supplied depends on the outdoor temperature, and in making the calculations, a survey of temperatures is usually made for the preceding ten years. The minimum temperature is not taken as a basis, but a fair average of the lowest temperatures is used, which should be not more than 15° F. above that minimum.

The fuel consumption for heating purposes is proportional to the number of "degree days" for the heating season in the particular locality concerned. A "degree day" is a unit based upon temperature and time, and for any one day there are as many degree days as there are degrees Fahrenheit difference in temperature between 65° F. and the mean atmospheric temperature during that day.[3] Average values for North America are given in the Guide of the American Society of Heating and Ventilating Engineers. The following Canadian values apply to the period 1940 to 1946, and are compared with average figures for some European cities—

Canada		*Europe*	
Winnipeg:	10,199 degree days.	Moscow:	8,712 degree days.
Edmonton:	9,696 " "	Bergen:	6,012 " "
Ottawa:	8,590 " "	Breslau:	5,670 " "
Montreal:	8,219 " "	Vienna:	5,238 " "
Toronto:	6,976 " "	Paris:	4,302 " "

The heating load depends upon the difference between normal heat losses and the heat supplied by persons and processes. In some instances, as in furnace rooms, the heat supplied in this way is more than sufficient to maintain the required temperature and no auxiliary heating is necessary.

The quantity of heat given out by adults at rest and working, respectively, varies from 400 to 800 British Thermal Units per hour and, where lights or machinery are working the whole of the energy supplied to them is converted into heat.

[1]These figures refer to Canada and the U.S.A. Lower standard temperatures are used in England. For details see *Principles of Heating and Ventilation*, by H. M. Vernon, Chap. I.

[2]From the *Guide of the American Society of Heating and Ventilating Engineers*. Further details are given in *The Mechanical Equipment of Buildings*, by Harding & Willard, and in other similar works.

[3]*A.S.H.V.E. Guide.*

Losses of heat are due to four causes—

1. Normal leakage of heat through walls, windows, and roof (materials).
2. Infiltration, or leakage of air through walls, windows, and doors.
3. Exposure of walls to winds.
4. Heat required to warm air admitted for ventilating purposes.

The first loss may be reduced by using heat insulating materials. These may be obtained in board, blanket, or powdered form, and their relative insulating values are given in the standard works on Heating and Ventilation. Such comparisons, however, must be made with discrimination, for the following reasons—

(*a*) The heat transmission coefficient depends on the thickness of material.[1]

(*b*) Materials are made in various densities, and care should be taken to see that the material offered is of the same density as that assumed in making the calculations.

(*c*) Where moisture, fire risk, or vermin are likely to be present, the material chosen should be of a suitable nature to resist their action.

(*d*) The heat transmission coefficient depends on the mean temperature used in making the test, so that two test results should not be compared if widely different temperatures were used.

(*e*) When powdered materials are used, the density of packing and their liability to settle or pack are important factors.

(*f*) The comparison must be on the basis of ***heat insulation per unit of expenditure*** and not on the relative amounts of heat transmitted per unit of thickness.

These facts must be taken into account when a factory or other building is being erected. Test results are also available on complete walls, and the Nicholls heat meter[2] provides a method of measuring heat losses from actual buildings. Air infiltration can only be reduced by good construction and by providing weather stripping round doors and windows.

An exposure factor must be used to allow for extra heat

[1]See *Engineering Research Bulletin No. 149,* University of Toronto; "Heat Insulation as Applied to Buildings and Structures."

[2]See *Trans. A.S.H. & V.E.* 1924, and "Flow of Heat through Walls," Giesecke, *Heating Piping and Air Conditioning,* December, 1938, p. 802.

losses due to winds of high velocity or to low temperature on the exposed sides of the building.

Rooms or shops may be heated by hot water, steam, air, or electricity.

The first has the merit of simplicity and flexibility, as any desired temperature may be maintained, but the circulation must be forced by means of a pump if the floor area is large.

Steam supplied under a pressure of from 2 to 10 lb. per square inch is relatively inflexible, but when a vacuum pump is used, the temperature can be varied by reducing the steam pressure.

Air heating may be supplied from a central heater in which steam is used, the air being forced over the heating elements by means of a fan and distributed through large ducts. This is called a "hot blast heater." Alternatively, smaller heaters, called unit heaters, may be installed at suitable points in the shop to give proper distribution of heat without using ducts.

Electric heating is generally too expensive for factory use unless a large supply of electricity can be obtained at a very cheap rate. It is applied in the form of heated panels in some parts of England. This is called "radiant heating" and is also being applied to some buildings by means of heated pipes buried in the floor, walls, or ceilings.

The use of exhaust heat from engines, turbines, or processes is usually the cheapest method where such supplies are available, and many large central heating plants, such as that at the University of Toronto (Fig. XI.1.), are operated in this way.

Automatic control of the heating system by means of thermostats placed in different parts of the building or plant is now quite common, and this frequently saves a great deal of money by adjusting the heat supply to the changing conditions. Heating systems in large buildings are now frequently arranged in sections or "zones" which can be controlled independently so that the correct temperature is maintained in each zone.

Condensation of water on the interior surface of a building may cause considerable trouble in the form of short circuits, corrosion, or rotting of materials. It can be avoided by installing a sufficient thickness of heat insulation, or by increasing the velocity of the air passing over the surface. Formulae and charts are available, showing what thickness of insulation is necessary for this purpose.

Condensation in hollow walls may be prevented by installing a vapour-proof barrier on the *warm* side of the air space.

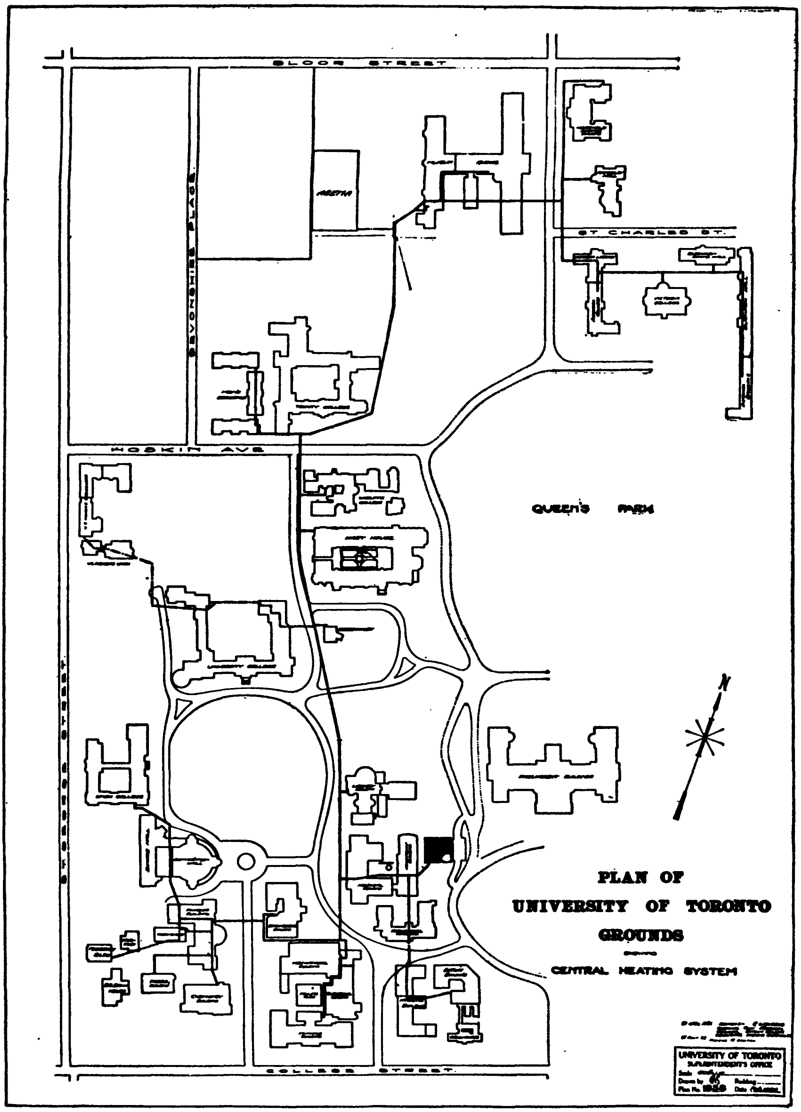


FIG. XI.1. CENTRAL HEATING SYSTEM AT UNIVERSITY OF TORONTO
(The black square in the plan shows the position of the central heating plant and the thick lines indicate the heating mains.)

The above is a very brief summary indicating some of the principal factors that arise in connection with the heating of factories and other buildings. Further details may be obtained from books and papers that deal exclusively with this subject.[1]

Ventilation and Air Conditioning.

The object of ventilation is to replace the vitiated air in a room or building by pure air, and to distribute it without causing discomfort; that of air conditioning is also to adjust the temperature and humidity of the air introduced to give the maximum degree of comfort and well-being.

Air pollution is produced by the exhaling of carbon dioxide and water vapour, and by the accumulation of odours, dust, and bacteria from persons or processes. The feeling of discomfort in a crowded room is not due solely to the replacement of oxygen by carbon dioxide, but to the simultaneous increase of the humidity, the odours, and the bacteria content of the air. An abnormal percentage of carbon dioxide is therefore an *indication* of bad air conditions.

The amount of ventilating air to be supplied (including recirculated air) varies considerably with the nature of the work and with the conditions under which it is done, but an average figure is about 2,000 cub. ft. per person per hour, or from three to five changes of air per hour. If considerable amounts of dust or gases are given off from a machine or process, exhausters must be used, so that the health of the workers will not be affected thereby.

The air must be introduced at such points and in such a way that no draughts will be produced. The air velocity, relative to the individual, should not exceed 40 ft. per minute, and the temperature of the incoming air should be not more than 2° F. below the temperature of the air in the room[2].

Methods of ventilation are divided into *natural* and *mechanical* types.

The former are those which use the wind or convection currents, due to differences of temperature, and are not so easy to control as the latter. Doors, windows, stationary and rotating roof ventilators are used for this purpose, but with them no air conditioning is usually possible. Mechanical systems may be operated from a central source of supply, the air being carried by

[1]E.g. Jrl. Royal Architectural Institute of Canada, Mar. 1947. "Use of heat insulation in Building Design and Construction"—E. A. Allcut.

[2]*A.S.H. & V.E. Guide*, 1946 Edition, Chapter XII.

ducts to the distributing points. The air may be washed, heated, cooled, or given the desired degree of humidity at the central point, or the heating system may be entirely separate. Exhaust systems, which reduce the pressure in the room below that of the surrounding atmosphere, are used in cases where gases, odours, or dust must be removed.

The air conditioning apparatus filters and washes the air to remove dust, adjusts its temperature by means of heating coils, or cools it by the use of cold water pipes or refrigerated brine.

The relative humidity of air is the ratio of the actual weight of water vapour contained in it to that present when the air is saturated at the same temperature. It is a well-known fact that the same feeling of comfort will be experienced with a high temperature and low relative humidity as with a low temperature and high relative humidity.

This phenomenon is indicated by the term "*effective temperature*,"[1] and its value for different air temperatures, humidities, and velocities is plotted on a "psychrometric chart." This shows that the same feeling of comfort is derived from a temperature of 68° F. with a relative humidity of 10 per cent as from a temperature of 64° F. with a relative humidity of 70 per cent.

Carrier estimates that, in some instances, production has been increased from 10 to 18 per cent by proper air conditioning, and states that the fuel bill can also be reduced by using lower temperatures and proper humidification. In cases where the humidity is already too high, similar apparatus can be used for de-humidifying the air. A correct amount of humidity is also necessary in food, drug, textile, and printing work,[2] particularly in cases where static electricity is liable to cause operation troubles. Humidifiers, in the form of water or steam jets, are sometimes distributed about the shops to maintain the proper conditions. The average comfort zone for winter conditions is contained within the range 63° to 71° F. effective temperatures, and for summer conditions the comfort zone is from 66° to 75° E.T. These standards were based on experiments made at Pittsburgh by the American Society of Heating and Ventilating Engineers, and later experiments made at Toronto and in Texas indicate that some modifications may be necessary in different localities.[3]

[1]See Appendix I and *A.S.H. & V.E. Guide*.

[2]Details are given in *Principles of Heating and Ventilation*, Chap. XI (H.M. Vernon) and *A.S.H. & V.E. Guide*, Chap. 45 (1946 Ed.).

[3]"Cooling Requirements for Summer Comfort Air Conditioning," *Heating, Piping and Air Conditioning*, December, 1936.

As indicated above, refrigerators are sometimes used for air cooling, but alternative methods are those involving the control of humidity and the use of air motion for this purpose.

With summer cooling systems, changes in the intensity of illumination are liable to affect the operation of existing air conditioning plants. S. R. Lewis[1] gives an example of a department store basement in which the heat received from electric lights was equivalent to 400 square feet of radiation and amounted to 46 per cent of the total cooling load. A new lighting system involved an investment of $6000 in cooling plant to remove the surplus heat.

Lighting.

Inadequate lighting and lack of uniformity in the distribution of light have a considerable influence on the efficiency and health of the workers. Production tests have shown that increases of output ranging from 15 to 25 per cent, have resulted from improvements in the lighting system.

A summary of several tests made in this connection is given in the following table which has been reproduced from a paper[2] read by Messrs. Munroe and Cook, of the Detroit Edison Company—

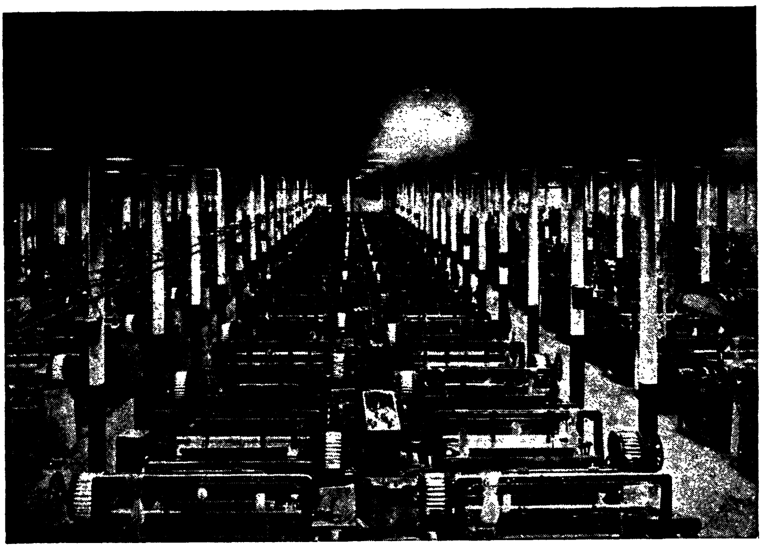
COMPARATIVE PRODUCTION WITH OLD AND NEW SYSTEMS OF FACTORY LIGHTING

Shop	Average Foot-Candles with Old System	Average Foot-Candles with New System	Increase in Production with New System per Cent	Additional Lighting Cost per Cent of Pay Roll
Pulley Finishing (Pyott Foundry Co.)	0.2	4.8	35.0	5.0
Soft-metal Bearing (Foote Bros.)	4.6	12.7	15.0	1.2
Heavy Steel Machine (Lee, Loader & Bondy Co.)	3.0	11.5	10.0	1.2
Carburettor Assembly (Stromberg Carburettor Co.)	2.1	12.3	12.0	0.9
Plant Manufacturing Electric, Gas and Sad Irons (Dover Mfg. Co.)	4.0 at tool point	13.5	12.2	2.5
Semi-automatic, Buffing Brass Shell Sockets (General Electric Co.)	3.8	11.4	8.5	1.8
Manufacturing Piston Rings (Detroit Piston Ring Co.)	1.2	18.0	25.8	2.0
Letter Separating (U.S. Post Office Dept.)	3.6	8.0	4.4	0.6
Inspection in Roller-bearing Plant (Timken Roller Bearing Co.)	2.0	20.0	12.5	2.5
Average	2.36	12.5	15.0	1.97

[1] *Heating Piping and Air Conditioning*, March, 1939, p. 145.
[2] *Trans. A.S.M.E.*, MAN, 51–8, 1929.

(*Courtesy of Canadian General Electric Co., Ltd.*)

FIG. XI.2. BADLY-LIGHTED TEXTILE MILL



(*Courtesy of Canadian General Electric Co., Ltd.*)

FIG. XI.3. SAME MILL AS IN NO. XI.2. WITH IMPROVED LIGHTING

The greatest number of accidents[1] occur during the winter months when artificial lighting is prevalent, and it has been calculated that about 75 per cent of the spoilage also takes place at this time. One body-making plant alone saved $3,000 per year in spoilage on a single operation by improving the lighting. Defective eyesight, due to poor illumination, has a considerable effect on the health and productivity of the workers, and good lighting is considered to have a considerable influence on labour turnover. It has been stated that 25 per cent of a man's bodily energy is used in seeing (Mayo Clinic). Illumination and cleanliness are closely allied, and a well-lighted plant is likely to be well kept. Adequate supervision is also facilitated by this means.

It is generally desirable to have a steady light, free from flickering, of the proper intensity for the work to be performed.

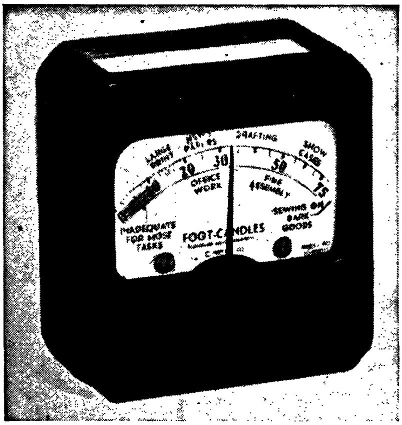


FIG. XI.4. GENERAL ELECTRIC LIGHT METER

The General Electric Company[2] gives the following average guide for intensity—

5 ft. candles—satisfactory for work of a coarse nature and for warehouses, stores, aisles, and passageways.
10 ft. candles—good lighting for most work on light-coloured surfaces and for fairly close work on dark surfaces.
15 ft. candles—excellent lighting for fast and accurate production.
50–100 ft. candles—exceptional for local lighting on very fine work.

The colour of the light is important in some operations, such as those involving grading, sorting, and matching. Glare, or

[1]See Fourth Report of the Departmental Committee on Lighting in Factories, H.M. Stationery Office, 1938.
[2]Bulletin 42–A, Engineering Department, National Lamp Works.

high local intensity, which results from improper distribution or diffusion, must be avoided as it produces eye-strain.

The unit of light is called a *lumen*. It is the quantity that will light 1 sq. ft. of surface to an average intensity of one *foot-candle*. The fraction of the lumens generated that reaches the surface to be illuminated is called the *coefficient of utilization*. The *depreciation factor* indicates the loss of illuminating capacity that is due to aging of lamps or to the accumulation of dirt, which reduce the transmission and reflection of light.

Lighting is divided into two kinds, namely, *natural* and *artificial*. The daylight record at Washington showed that on a summer day during working hours, the intensity of sunlight varied from 2,000 to 9,000 *foot-candles*,[1] and this variation is supplemented by those due to the seasons of the year. Other variable factors are due to the cleanliness of the glass, the kind of glass used, and the incidence of the light on the windows. Higbie and Randall[2] give the following curve (Fig. XI.5.) illustrating the loss of light transmission from accumulations of dirt. With normal incidence, the transmission was reduced from 80

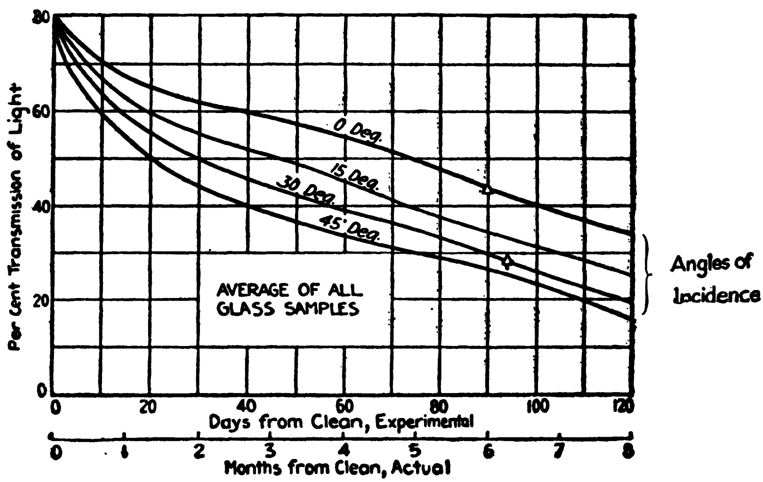


FIG. XI.5.

AMOUNT OF LIGHT TRANSMITTED BY WINDOWS, AS PER CENT OF THAT WHICH IS AVAILABLE, IS MARKEDLY REDUCED BY ACCUMULATIONS OF DIRT, PARTICULARLY IN THE FIRST FEW WEEKS AFTER WASHING THEM, AS SHOWN BY BOTH FIELD TESTS AND LABORATORY EXPERIMENTS

[1]The curve is given in *Industrial Engineering and Management*, Barnes.

[2]*Trans. A.S.M.E.*, January–April, 1929, MAN, 51–8; also, *Engineering Research Bulletin*, No. 6, University of Michigan.

to 35 per cent after eight months of exposure. The average transmissions for clean glass were given by them as follows—

	Direct Light	Diffused Light
	%	%
Clear Plate Glass	90	84
Rough Rolled Glass	83	76
Prismatic Glass	63	53

The variation of daylight illumination over the floor of a building 80 ft. wide (Fig. XI.6.) indicates the necessity of supplementing natural by artificial lighting. It is usually considered that the working space is limited to a distance from the wall of three times the height of the window, and if the windows become dirty, this may be reduced to two-thirds of that distance.

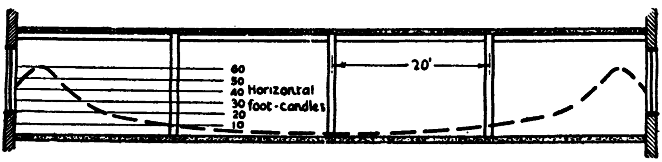


Fig. XI.6.

Variation of Daylight Illumination in a Building 80 ft. Wide

The necessity of high windows is thus indicated. This is accentuated by the statement of Benford, in the discussion of the paper mentioned above, that with a window 12 ft. high, 1 in. at the top gives as much light as 1 ft. at the bottom. Notwithstanding these variables, a method of calculating the illuminating effect of daylight is given in the original paper and checked by actual results.

Multi-storey buildings introduce difficulties of shadows and light obstruction, and the advisability is indicated of using light-coloured materials for adjacent walls, so that reflection of light may assist the lighting of the lower floors. It is suggested that the distance between buildings should be not less than their height, but this is frequently impracticable on account of limitations of space. Buildings are now being erected in which most of the side walls consist of glass. This increases the illumination but adds to the heating load.

A recent development is the design of buildings with no windows at all. A good example of this is the office building of

Hershey Chocolate Corporation,[1] which covers an area of 150 ft. by 350 ft. and has three storeys and a basement. It is claimed that elimination of heat leakage through windows and proper insulation of the walls and roof will result in a 5 per cent decrease in the cost of operating the air conditioning plant. The lighting load is 2½ watts per sq. ft. of floor area and a minimum of 15 cub. ft. of outside air is introduced per person per minute, with a complete change of air every eight minutes. As the lighting is entirely artificial, the illumination to all parts of the floor can be kept uniform at all times. Each desk is supplied with light from a combination of mercury vapour and filament lamps arranged to give a spectrum approaching that of pure sunlight. The intensity is 20 foot-candle

Another innovation has been the use of hollow glass blocks for building purposes. These also give light without air infiltration and are being used satisfactorily in a number of industrial and commercial buildings.

Monitors and saw-toothed (north light) roofs are frequently used in single-storey factory construction. They can be made to give good uniform lighting, provided they are so arranged that snow and dirt do not obscure them to any great extent.

Artificial lighting is almost invariably done by means of electric bulbs. Sometimes arc lights or mercury vapour lamps are used, but these cases are exceptional. Such installations may have general, group, or local lighting, and the distribution may be direct, indirect, or semi-indirect.

General lighting is arranged to give a good, uniform light free from deep shadows; group lighting gives special illumination to groups of machines or workers; local lighting gives illumination of special intensity to each particular worker or machine. Tables, giving the height and spacing of lamps for different intensities of lighting,[2] are provided by lamp-makers.

Direct light is liable to produce glare unless it is placed sufficiently high to avoid catching the eye. Indirect lighting has all of the lamps hidden, the light being reflected by walls, or ceiling, or both, so as to give a light of uniform intensity. The colour of the interior finish is important, as white paint reflects about 80 per cent of the light it receives, while dark brown or green paint reflects about 15 per cent. Semi-indirect lighting

[1]See *Modern Power and Engineering*, April, 1936.

[2]Examples are given in *Industrial Engineering and Management*, by Barnes, pp. 119–122, and in "Illumination Design Data," Canadian General Electric Co.

uses translucent shades to transmit some of the light, and reflection from the interior surfaces of the room supplies the remainder of the illumination.

Maintenance is important, to keep the depreciation factor within reasonable limits. The lights should be cleaned at regular intervals, and so should be readily accessible for this purpose.

After being in use for some time, the light given out by an electric bulb is considerably reduced, and therefore the lamps should be replaced when their useful life is finished. Some member of the staff should be made definitely responsible for this work, otherwise the lighting system will become inefficient, even though it was properly installed in the first place.

It is suggested in the American Standard Code of Lighting that, as the compensation insurance premiums depend on the average number of accidents, and as efficient lighting tends to reduce the accident rate, it may easily happen that the increased cost of such lighting may be paid for wholly or in part by the reduction in annual payments for insurance purposes.

Fluorescent lighting is now being used in modern buildings to give shadowless "cold light" and is a feature of the windowless plant of the Simonds Saw & Steel Company, Fitchburg, Mass. In this five acre room there are no partitions between office, furnaces and manufacturing plant, but the atmosphere is kept pure by the air conditioning plant and exhaust systems. Sound insulation is employed to deaden the noise.[1]

Noise.

Noise is an irritant and, if intense and prolonged, may produce deafness; but there are also other injurious effects, such as insomnia, fatigue, emotional disturbances and neuroses. Loud and sudden noises are dangerous, particularly to the eardrums or the bony structure of the middle ear. High pitched tones appear to be more dangerous than tones of low pitch. Noisy work performed in an enclosed space is more harmful to the ears than it is in the open air, as reverberation and reflection accentuate the noise. For these reasons, particular attention is now being paid to the reduction of this irritating factor by—

(*a*) reducing the noise at its source;

(*b*) the use of sound insulation;

(*c*) the use of ear plugs or other personal protective devices.

It is claimed that, in a telegraph office, reduction of the noise

[1]*Mechanical Engineering*, August, 1939, p. 615.

level from 50 to 35 decibels reduced errors by 42 per cent. Also, in an assembly department rejections were lowered from 75 to 7 per cent when it was moved from a very noisy to a quiet location. In a packing room equipped with a noisy ventilating fan, the output increased by 12 per cent when the fan was stopped, in spite of the poorer ventilation. Further, in a weaving operation the use of "ear defenders" increased the operative efficiency by 8 per cent.

It is not to be expected that these improvements will always follow the reduction of noise intensity, but this factor will certainly bear investigation when plants or offices are being designed or re-modelled.

Arrangements of Departments and Machines.

The departments and buildings required in the average manufacturing plant may be classified roughly under four headings—

1. *Offices.*
   - (*a*) General and commercial.
   - (*b*) Drawing.
   - (*c*) Planning and progress.
2. *Storage.*
   - (*d*) Receiving and raw materials.
   - (*e*) Partly finished materials.
   - (*f*) Finished materials.
   - (*g*) Patterns, dies, and similar manufacturing facilities.
3. *Manufacturing.*
   - (*h*) Machining or processing.
   - (*k*) Assembly or erection and testing.
4. *Service.*
   - (*l*) Tools, gauges, etc.
   - (*m*) Maintenance.
   - (*n*) Power.
   - (*p*) Wash rooms, rest rooms, canteens and welfare centres generally.

Types of building[1] are indicated by the letters I, L, T, U, etc., according to the ground plan employed, and where natural lighting is employed the principal axis should be from east to west so that north and south windows may be used.

The relative positions of the manufacturing departments depend on the site available, the arrangement of the buildings and

[1]For details and relative advantages, see Jones, *Administration of Industrial Enterprises*, Chap. IV ("Layout of a Manufacturing Plant").

the kind of work done. Continuous processes are preferably carried out in a straight line. That is, the material is continually moving forward and does not retrace its steps. With multi-storey buildings this may involve the use of gravity, the processes starting at the top of the building and the material gradually moving downward until it leaves at the ground level. Single storey buildings may be arranged so that the material moves forward on the same level from the raw material stores to the finished stores, but the attainment of this ideal is subject to certain modifying influences. The receiving and shipping departments should be near a railway siding or other transport agency. The same machine may be used for more than one process, or one man may perform several operations, not necessarily consecutive ones. Heavy or noisy machines, or operations requiring certain conditions of safety, lighting, or moisture, may have to be placed in certain positions, irrespective of the sequence of operations. In such instances, material transport difficulties may be less serious than the possible alternatives.

Continuous, or mass production work, is usually departmentalized by *products* and the machines are arranged to perform consecutive operations on a single piece of work. Special or intermittent work is arranged according to *processes*. Each department or section contains a particular class of machine, or is arranged for doing a particular type of work, e.g. turning, drilling, or milling sections.

The selection of machinery must be on the basis of its expected life[1] and saving of cost, after taking into account probable depreciation, obsolescence, and repairs. Most kinds of machine have increased considerably in productivity during the last twenty years, and in some instances it pays to replace a machine by one of a newer type long before its natural life is finished. The increased use of automatic and semi-automatic machinery has increased production and decreased labour cost to a very considerable extent, and the substitution of simultaneous for consecutive operations has intensified this tendency.

Standard machines are usually lower in first cost and have a higher resale value than *special* machines, but the latter are frequently simpler, have a higher output and lower labour cost. They must pay for themselves in a comparatively short time, however.

[1]See "Economic Life of Equipment," by Vorlander and Raymond. *Trans. A.S.M.E.* Paper R.P. 54–2, 30 July, 1932.

Power consumption and the type of labour required must also be considered when new equipment is being purchased.

When installing machinery, its relation to other manufacturing operations and the floor space necessary for its accommodation must be considered. The usual method is to consider each machine or group of machines as a *production centre* which includes not only the space taken up by the machine itself, but also that necessary to work it, including storage of raw and finished parts and a proportional share of the gangway. Adequate foundations must be provided to ensure freedom from excessive vibration when working at full capacity, and the machine should be inspected and tested to see that these conditions have been observed.

The arrangement of the machines depends on the method of driving, the floor space available, and the flow of work. Col. Geo. S. Brady has listed the important factors in plant layout, as follows[1]—

1. A work flow sheet of all the products processed in the factory departments.

2. Provision for convenient receipt of all raw materials. Some quantity materials will go to storerooms; some will go directly to manufacturing departments, such as forge shop or screw-machine department, which should be properly located for receipt of raw material and delivery of the manufactured parts to a parts storeroom handy to the using departments. Watch for choke points on elevators.

3. Where supervision demands the grouping of machines of a single type, like drill presses or milling machines, the other departments must radiate from these groups. Sometimes it is advisable to have separate heat-treating equipment in a department to save the confusion arising from repeated back-and-forth trips of parts.

4. Some heavy equipment will necessitate installation on a ground floor. Other equipment will require installation under a heavy crane. Sometimes a slight change in design of the part will permit all operations on this heavy equipment to be done at one time and thus save moving back and forth.

5. Storekeepers are usually jealous of their prerogatives and will want all raw materials stored in a common storeroom. Sometimes it is more economical to provide departmental sub-

[1]*Mechanical Engineering*, May, 1945, p. 332.

storerooms and permit the foremen to draw or receive quantity lots and store them close to the point of use.

6. When the first general layout of machines and equipment is made, check for window space, clearance, lighting, power outlets, ventilation, proper spacing of workers, and distances to washrooms and drinking fountains. See that welding equipment and machines drawing heavy current are not located where heavy power cables must be run through the plant.

7. Check floor loads with inclusion of weight of work in process and in maximum storage. Also check all ceiling and other clearances for the work.

8. Check all trucking and other transportation considerations. Provide ample aisles. Suggest conveyors and chutes where they are economical. Adequate pavements or covered walks should be provided between buildings where there is back-and-forth trucking.

9. Departments requiring live steam or compressed air must be located conveniently to the sources, or separate provision must be made.

10. Tool cribs are preferably placed in each department, but by clever arrangement they can sometimes be made to serve several departments, with consequent saving in manpower and inventory of tools.

11. Noise is hard on the nerves and interferes with production. See that drop hammers, saws, grinders, and other noisy equipment are away from the majority of workers. Protection should be provided against flashing of welding equipment.

12. In considering these points provide flexibility in each department and on over-all layout, so that changes can be made to provide for changes in type of work or quantity of lots.

13. When the layout is completed, devise a regular, continuous, and scheduled system for the delivery and pickup of mail to and from each department so that each foreman will feel that he is effectively linked into the whole system. This centralized mail system should take care of speedy delivery on regular routes so that departmental messengers are unnecessary.

Lists of the power required to drive individual machines may be obtained from the makers.[1] There are three methods of driving them—

1. *Main drive* from a single engine or motor. This is now seldom used except in small shops.

[1]See also *Machine Shop Management*, by Van Deventer, Sect. III.

2. *Group drive* in which a number of machines are driven from motors placed at strategic points in the shop. This is more flexible than the first method and gives less trouble from breakdowns.

3. *Individual motor drives* in which each machine has its own motor, or, in the case of a large machine, may have several motors for different operations. This is the most expensive method, but is also the most flexible. It is being adopted to an increasing extent.

Combinations of methods 2 and 3 are also used, in which some machines are grouped for driving purposes and others have their own motors.

Good maintenance is important in all machine shops to reduce breakdowns, as these are seldom sudden, but are usually due to progressive wear. Maintenance and power costs are generally less in the group drive than in the individual motor system.

The number of machines installed depends on their individual productivity in units per hour, the number of working hours per day, and the unproductive time for maintenance and repair processes. The operating times of the machines are fairly easy to estimate in the case of continuous processes, but with intermittent work, considerable economies may be obtained by proper planning and by balancing equipment and processes, so that there are no "bottle necks" to stop the steady flow of material through the works. Machine schedules in the Gantt or other form of chart will assist materially by indicating the amount of work on hand and available for each machine.

The floor space necessary depends on the number of, and space occupied by, the various production centres and, in hand work, on the space required for each worker to operate efficiently. Service centres, such as locker, wash, and rest rooms, should be near to the individual shops served by them, some compromise being necessary for convenience in plumbing and other arrangements. Some districts have laws which provide for the minimum number of wash rooms and other units per 100 employees. Provision must also be made for tool storage, inspection, research, offices and other necessary auxiliaries.

Models of machines and buildings are frequently used to study experimental layouts of processes (Fig. XI.8.).

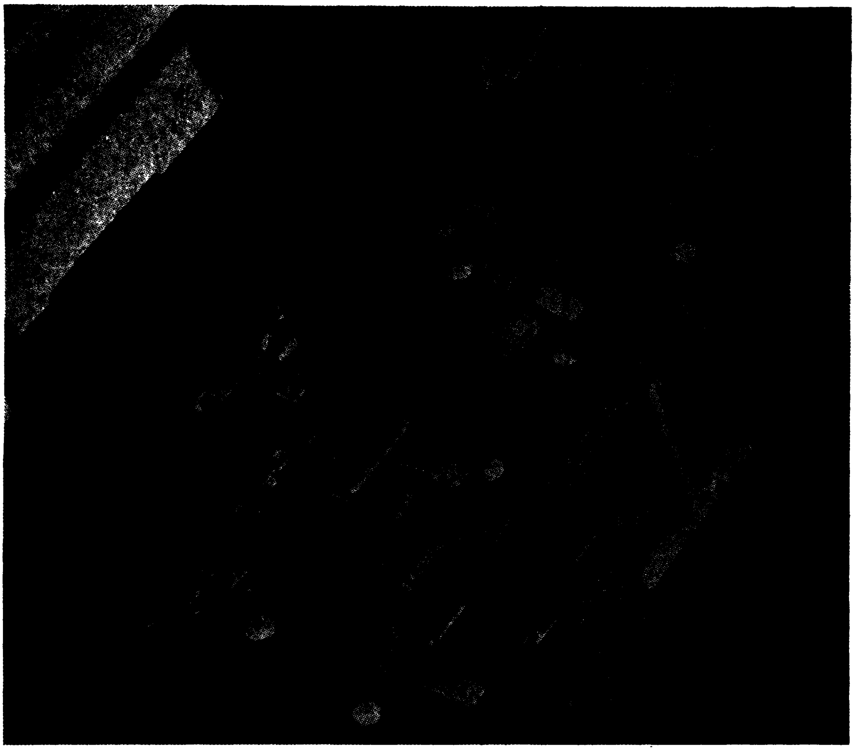
A card index or machinery list is usually kept. This contains machine numbers, name of worker, date acquired, production

FIG. XI.7. USE OF BELT CONVEYOR FOR THE CONTINUOUS ASSEMBLY OF CLOCKS
(Courtesy of Canadian Machinery and Manufacturing News)

and space occupied, and in some instances the speed, feeds, and forms of tool employed are standardized.[1]

Shop Transport.

The general remarks given in Chapter X on the handling of materials, also apply to questions of shop transport. Materials that are handled in bulk, such as flour, cement, and foodstuffs, are transported by conveyors (Fig. XI.9.) and elevators, and are piled mechanically. Parts that are made in unit form, such as castings or forgings, can also be handled in this way, provided

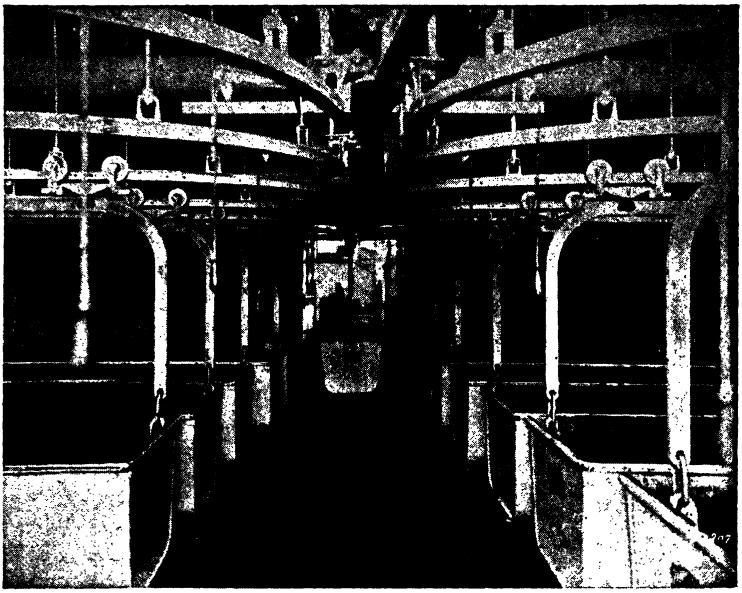


(*Courtesy of* Modern Industry)

FIG. XI.8. MACHINE MODELS FOR EXPERIMENTAL LAYOUTS OF PROCESSES

that their path is definitely established and invariably followed (Fig. XI.10.). Shops that produce machines or structures to special order, however, cannot be equipped in the same way. The conveying arrangements must be more flexible, such as overhead cranes for the heavy parts and electric trucks for the light ones, so that a single transporting device may be used for a

[1]See *Machine Shop Management*, by Van Deventer, pp. 105–139.



(*Courtesy of Riley Engineering and Supply Co., Toronto*)

FIG. XI. 9. BATTERY OF DOUGH TROUGHS SUSPENDED ON AMERICAN MONORAIL TROLLEYS

(*Courtesy of* Canadian Machinery)

FIG. XI.10. CONVEYORS IN MASSEY-HARRIS COMBINE PLANT

number of different jobs. The value of mechanical handling devices is best shown by their use in repetitive work (Figs. XI.11. to 14.). Here, the time taken to move an article from one process to the next is *lost* time, and the process absorbs a large amount of unproductive labour. When the value of the time and labour saved is greater than the cost of installing conveyors, it pays to substitute mechanical handling for hand labour. The laws of economy for labour-saving devices are given by the American Society of Mechanical Engineers.[1]

They were developed for and adopted by the Materials Handling Division of The American Society of Mechanical Engineers in 1925, and provide means for economic analysis of manufacturing to show the savings that have accrued or may be secured from improved mechanical equipment.

For some control problems, particularly those of internal transport, photo-electric relays are very convenient.[2] These are

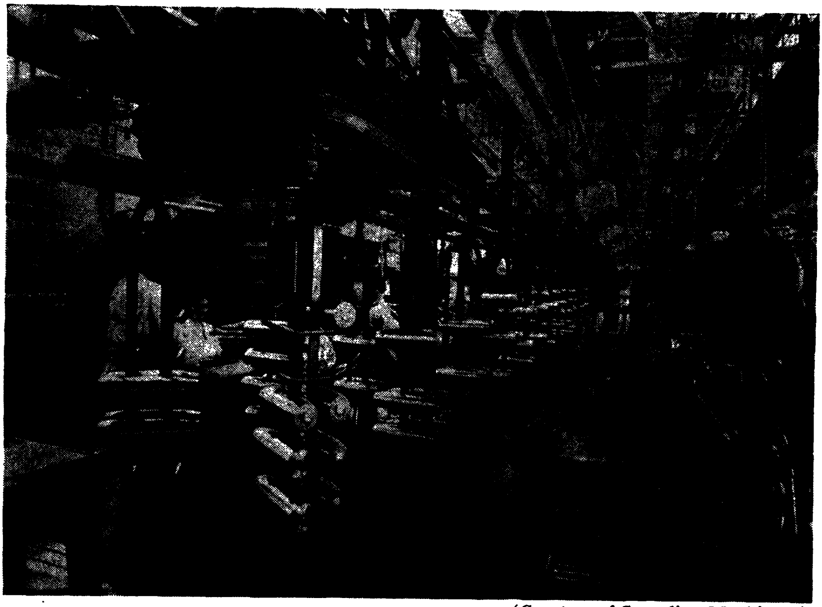
(Courtesy of Link-Belt Co., Toronto)

FIG. XI.11. CONVEYING EQUIPMENT CARRYING ENGINE PARTS FROM HEAD OF INCLINED CONVEYOR SHOWN BELOW

The large increase in production of automobiles by the several prominent American manufacturers was made possible only by the use of modern time and labour saving equipment, and today these concerns are practically dependent upon mechanical, efficient labour saving conveyors

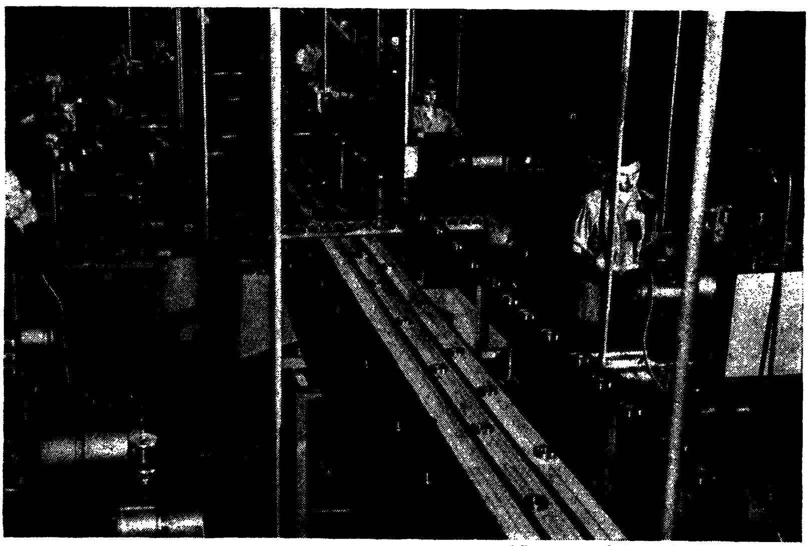
[1]*Mechanical Engineering*, May, 1925.

[2]Details of these are given in *Canadian Machinery and Manufacturing News*, March, 1937, and in bulletins issued by the General Electric Co. Ltd.



(*Courtesy of* Canadian Machinery)

FIG. XI.12. LINK-BELT CONVEYORS IN MANUFACTURING PLANT



(*Courtesy of* Canadian Machinery)

FIG. XI.13. CONVEYORS FOR BEARING RACES AT MCKINNON INDUSTRIES LIMITED

(*Courtesy of* Canadian Machinery)

FIG. XI.14. CHAIN BELT CARRIES BEARINGS THROUGH CONTINUOUS WASHER

applied also to counting, sorting, measuring, weighing, inspecting, signalling and regulating, and operate on light flashes or interruptions of very short duration (1/15 to 1/10,000 second, depending on the type). This does not necessarily mean that they can be made to operate a correspondingly large number of times per minute, as the latter factor is limited by the magnetic device which forms part of the relay. They are used to control cement mixtures automatically, to count refrigeration units on a production line, to start paint sprayers at the correct moment, or to dispatch boxes or bags to any station in a pre-selective conveyor dispatching system (Fig. XI.15.). They have also been arranged to shut down conveyors automatically when the pile of material in a hopper reaches a pre-determined height and for the automatic operation of doors. Photo-electric relays have been used to sound alarms when the turbidity of a solution changes due to breakage of a filter and for controlling the rate at which strip is fed into a machine so that printing or cutting is properly synchronized.

Materials that are easily damaged should be given special protection or be packed in specially designed containers. One firm had considerable trouble with chipping of hardened gears. They attributed this to defective case-hardening. After investigation, it was found that the labourers employed in conveying

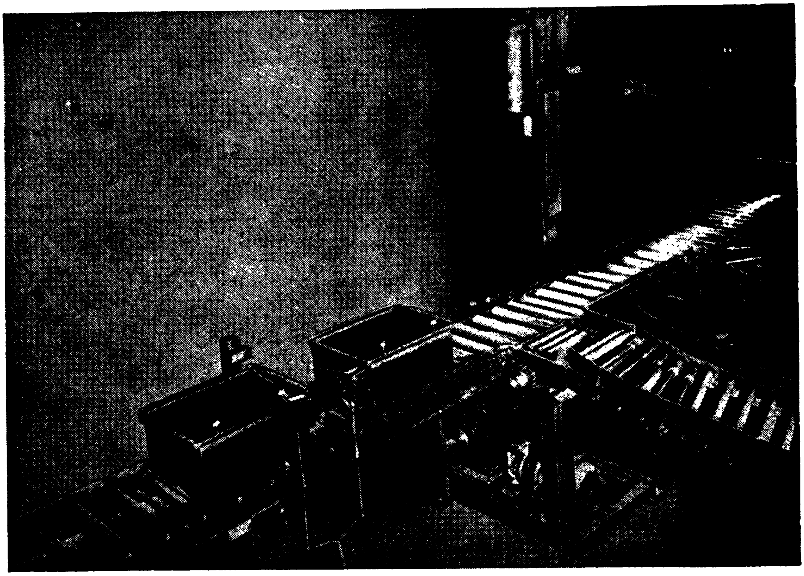


Fig. XI. 15. General Electric Photoelectric Relay and Light Sources on a Preselective Conveyor Dispatching System Manufactured by the Logan Conveyor Company of Louisville, KY

the gears from one shop to another, were in the habit of throwing the gears into the electric trucks and shaking them considerably in transit. This was rectified by making special boxes with wooden partitions that prevented the gears from coming into contact with each other. No more trouble was experienced.

Economic Lot Sizes.[1]

With intermittent production the question arises, "How many units shall be put through the factory at one time?" If small quantities are made, the time of setting up and dismantling machines, and other expenses incidental to the change from one job to another, will be greater per unit than when large quantities are produced. On the other hand, the manufacture of large quantities at any one time involves greater storage cost and losses due to deterioration and possible obsolescence. Evidently, then, there is some quantity that will give the smallest overall unit cost. Formulae and curves have been calculated for this purpose,[2] and the principles involved are illustrated by the

[1]See *Quantity and Economy in Manufacture*, by F. E. Raymond (McGraw Hill, 1931).

[2]The details are too long and complicated to be considered here, but some of them are given in *Economic Production Quantities*, by F. E. Raymond, *Trans. A.S.M.E.*, Man, 50-10, January-April, 1928, and in another paper by the same author in *Trans. A.S.M.E.*, Man, 52-22, January-April, 1930.

curves in Fig. XI.16. It is evident that the unit cost of production is the sum of three factors, one of which (*A*) remains constant, one increases directly with the lot size (*B*), and the third (*C*) varies inversely with the lot size. Best, in his paper, "Twelve Years Experience with Economic Production Quanti-

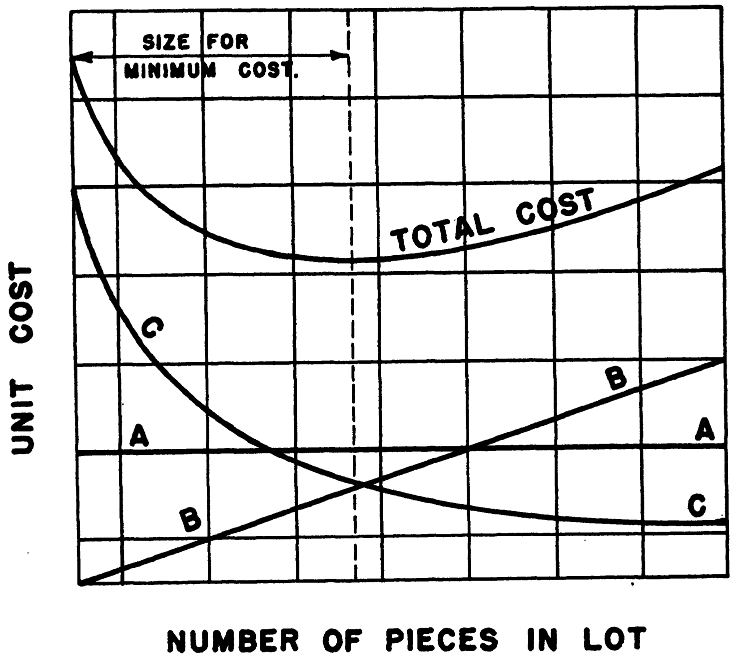


FIG. XI.16.

A.A. COST OF MATERIALS, LABOUR AND OVERHEAD (PER UNIT)
C.C. COST OF PREPARATION (PER UNIT)
B.B. INVESTMENT AND STORAGE PER UNIT

ties,"[1] states that the firm of Eli Lilly & Co., manufacturers of pharmaceutical products, were enabled to reduce their inventory of raw materials by 21½ per cent by the use of this principle, and that they had increased their production considerably. It is probable that no one formula can be employed universally for this purpose, but the following law and an appropriate formula[2] are given by way of example—

The law of economic lot size is—

The quantity of product that can be manufactured at the lowest unit cost varies directly as the square root of the preparation costs

[1] *Trans. A.S.M.E.*, Paper No. MAN, 52–2A.
[2] Alford's *Laws of Manufacturing Management*, p. 416.

and inversely as the square root of the interest charge, and storage charge.

That is $$Q = \sqrt{\frac{A}{K + H}}$$

where

Q = the most economic number of pieces to manufacture.
A = total cost of preparation for manufacturing.
K = a constant where values depend upon the ratio F of the minimum ordering point quantity, to the theoretical minimum quantity withdrawn from stock during the manufacturing period.
H = storage factor (influence of storage charges on economic size of lot).

K (for F less than unity)
$$= \left[\frac{M + MS(2F - I) + FS^2(F - I)}{2M^2S}\right] C'I$$

K (for F greater than unity)
$$= \left[\frac{M + MS(2F - I) + 2S^2(F - I)}{2M^2S}\right] C'I$$

H (for F less than unity)
$$= \left[\frac{(M + SF)\ \{M + S(F - I)\}}{MS}\right] BE$$

H (for F greater than unity)
$$= \left[\frac{(M + S)\ \{M + S(F - I)\}}{MS}\right] BE$$

where

B = bulk factor, square feet of net storage space per unit.
C' = unit cost of quantity to be manufactured, in dollars.
E = storage charge expressed in dollars per square foot of net storage space per year.
I = current rate of interest.
M = yearly manufacturing rate.
S = yearly consumption rate.

Jigs, Tools, and Gauges.[1]

Tools for producing the work, and gauges for ascertaining when the desired dimensions have been reached, are necessary in most classes of engineering work, but jigs are only used when the

[1]See also *Plant Production Control*, C. A. Koepke, Chapter XV.

quantity to be made justifies the necessary expenditure. The design of these has been considered briefly in Chapter VI, but the arrangement of the tool room and questions of supply and replacement pertain to the shop. It is desirable that a list be provided of the jigs, tools, and gauges required for making each article in a mass production job. Both for this purpose and for convenience in storing and recording, they should be numbered. Standard lists of tools and gauges are sometimes useful where similar jobs have to be performed.

A central tool room, with facilities for grinding and repairing tools is frequently used, supplemented by departmental tool cribs for storing and issuing them. It is important to arrange a special place for each tool and to have a reliable checking and recording system, showing what tools are in use and who has them. Lost or mislaid tools absorb considerable time and reduce the productivity of men and machines, so that system in their arrangement is absolutely necessary. Special jigs or tools should be marked with the part and operation number on which they are to be used. Arrangements should be made to ensure that men leaving, or suspended, return all the tools in their possession before receiving their pay.

The tool store, or crib, should be the recognized distributing centre, and to it worn-out tools should be returned, so that wastage and theft may be eliminated. Other tools should be checked by means of reference gauges, or other necessary appliances, after grinding, and jigs should be inspected, preferably by the inspection department, before being issued for production purposes. The latter should be stored off the floor and in a location free from dampness and dust.

The tool inventory is a matter of considerable importance, and the number and value of tools stored and issued should be carefully checked. The value of the tool steel kept in stock is frequently great. This should be checked at the same time. It is desirable to paint a stripe of a definite colour down bars of tool steel to prevent mixing with other stock.

The manufacture of jigs in the factory, or their purchase from firms specializing in this work, depends upon questions of cost and delivery. Sometimes it is better to have jigs made in the tool room, even at greater expense, than to incur the loss of production due to late delivery or the possibility of inaccuracy in dimensions when they are obtained from an outside source. Each case must be treated on its merits.

Packing and Shipping.[1]

The relationship of this department to others varies in different industries. When the work is of a repetitive nature so that shipments are made from stock, packing and shipping may be under the control of the sales department. The work is then of a routine nature as the sizes, weights, and numbers of packages, and, in many cases, the methods of packing are standardized. The cost of packing can then be obtained by methods similar to those used for other manufacturing processes. A shipping order, giving details of the material to be sent away, together with evidence that the material has been passed by the inspector, is received from the stock or sales department. Packing cards are placed in the boxes or crates, giving the necessary order numbers, date of packing, and name of packer. A packing list, including the contents of the package and other necessary information, is placed in the box. Another copy is sent to the customer by mail, and a third is used for internal recording. Shipping records are kept in sufficient detail to enable consignments to be identified and traced. Where carload shipments are made, the probable requirements must be known for some days in advance, so that the number of cars necessary will be available at the proper time. A book, giving a record of freight payments, both inward and outward, is usually kept, so that these monies may be correctly allocated in the cost accounts. The shipping record must also contain a reference to the serial number of the machine, or other commodity, so that the destination of any particular machine is recorded for future reference. This may be valuable if disputes arise, or when repairs or renewals are necessary.

Machines or structures made to special order are handled in a somewhat similar manner. With these the need for adequate records is still more pronounced as the sizes and weights of packages are not easy to deduce from the detailed drawings. Such records should be available when future tenders of a similar nature are made, as they are of considerable assistance to the man who has to estimate the cost of packing and freight. The home and export records should be kept separate, as the weights of boxes and cost of packing in the latter cases is likely to be much greater than in the former. If a consignment has to cross the ocean, the cases must be more substantially made than where land transport is employed. In many instances they must be lined to prevent damage from sea water.

[1]See *Factory Organization and Administration*, by Diemer, Chap. XX.

CHAPTER XII

MOTION AND TIME STUDY

Principles and Objectives.

The measurement of materials is a comparatively simple matter, but the measurement or evaluation of work is very difficult because of the complications introduced by the human element. Under the military system of organization, workmen were usually paid in proportion to the time spent in the factory, irrespective of the amount of work done. As the principle of payment by results, or piecework, came into operation, the value of the work, or piece rate, was usually estimated by the foreman. The multiplicity of duties to be performed by this official has already been outlined in Chapter III, and his estimate of the time that a job should take, though based on experience, was generally little more than inspired guesswork. Payments, accordingly, were arbitrary as they were not based on exact knowledge, and consequently industrial disputes were frequent. With the increased use of piecework and the partial functionalization of industry, this portion of the foreman's work was delegated to a rate-setter, who estimated from a drawing of the part to be produced, the time that the job should take. A rough analysis was made, and in many cases this was checked by observing the time taken to make a number of pieces. This procedure failed to produce the desired result because over-all times established in this way failed to provide a definite standard of accomplishment. In many instances the operator deliberately reduced his speed while the rate was being set, and afterwards increased it somewhat. Even then the work was not being done to the best advantage, owing to the use of unsuitable facilities, wrong speeds and feeds, needless motions on the part of the workman, and deliberate restriction of output to avoid ratecutting.

The objects of motion and time study, therefore, as defined by Lowry, Maynard, and Stegemerten[1] are: "To subject each operation of a given piece of work to a close analysis,[2] in order that every unnecessary operation may be eliminated and to determine the quickest and best method of performing each

[1] *Time and Motion Study*, p. 6.

[2] See *Operation Analysis*, Maynard and Stegemerten.

necessary operation; also to standardize equipment, methods and working conditions; then, and not until then, to determine by scientific measurement, the number of standard hours in which an average man can do the job."

Thus, the general idea is similar to that of chemical analysis, the quantity of each time component being measured, and impurities, in the form of redundant times or motions, being detected for subsequent removal.

The object of motion study, therefore, is to improve and standardize conditions of work, and that of time study is to serve as a basis for the measurement of work and for setting wage rates. The last objective can only be relative, as these studies do not, and cannot, indicate the value of an hour's work, but they do introduce an element of consistency into the payment of labour.

The work of Frank B. Gilbreth in the bricklaying industry[1] aroused considerable interest in motion study. He found that the bricks were dumped anyhow near the bricklayer. The latter had to walk several steps to the pile, pick up a brick, walk back, turn the brick over, and put it into place. Gilbreth developed a special packet in which the bricks were right-side up and a new type of scaffold to avoid stooping. He ascertained the best way of using the improved equipment, reducing unnecessary motions to a minimum.

This method has been applied successfully to work of all kinds. An example of detailed motion study or process chart is shown in Fig. XII. 1., where the operations of a cashier in a large department store are analysed into their elemental components.[2] The following extract from the original paper by B. E. Lies and M. P. Sealy illustrates the method of applying this study to produce improvements in the conditions of work (Fig. XII.2.).

"Two particularly bad features were obvious in the lay-out of the desk. First, the box in which the cashier put the copy of the sales check which she retained was at the upper left-hand corner of the desk. The cashier stamped both copies of the sales check with the stamp, located on the lower right-hand corner of the desk, and then carried her copy of the sales check to the box, diagonally across the desk, the longest distance. It was desirable to keep the stamp on the right-hand side for ease in stamping with the right hand, but the sales-check box was relocated directly under the stamp so that one copy of the sales

[1] *Motion Study*, 1911.
[2] From *Trans. A.S.M.E.*, 1928, Paper No. MAN, 50–17A.
The meaning of the various symbols used in Fig. XII. 1. is explained in "Process Charts," by F. B. and L. M. Gilbreth, *Trans. A.S.M.E.*, December, 1921.

check is dropped into the box as it is withdrawn from the stamp. Eliminating this long "transport loaded" and "transport empty" in the cycle reduced fatigue.

Another improvement in the desk was the relocation of the dispatch tube, which had been behind the desk at the side next to the belt, so that the cashier had to turn partly around to reach it easily. Also, the mouth of the tube was very little larger than the carrier, so that the carrier had to be positioned very carefully when dispatching it. The dispatch tube was relocated in the centre of the desk but toward the side toward the belt, and a bell hopper was placed at the opening so

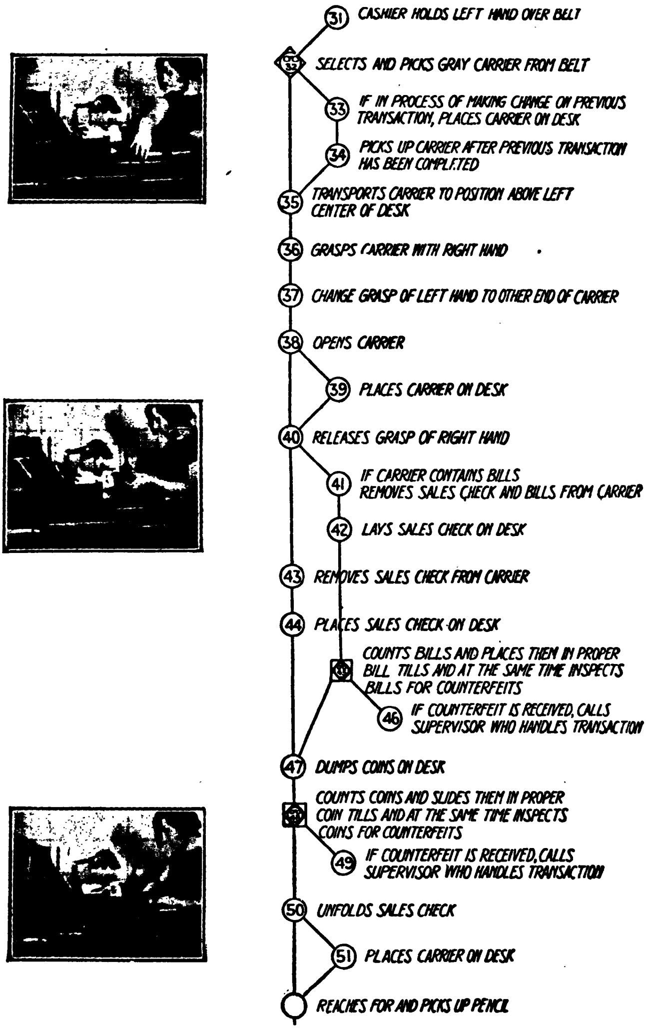


FIG. XII.1. PART OF MOTION STUDY OF CASHIER'S OPERATIONS

that the cashier could throw the carrier in with practically no positioning. Fig. XII.2. shows the layout of the old and new desks.

The new desks were made 36 in. high with a comfortable foot rest at the bottom, and a work chair with a double saddle seat, and adequate back support both for working and for resting was provided. With this equipment, the cashier easily alternates standing and sitting to reduce fatigue and the work place is equally convenient for both.

A locking device was also adopted, so that the cashier no longer has to pack up her money and take it to the office every time she leaves her desk. This device has reduced the "get ready" time.

Improvements were also made in the surrounding conditions. The desk lights were removed, and greater general illumination was obtained by installing larger fixtures of the proper type at regular intervals, thus providing an even distribution of light with a minimum of shadows. An average uniform illumination of 18 ft. candles was provided. Noise was lessened by covering the drums and air tubes with felt padding and the walls with acousticon. Ventilation in one tube room was improved by installing screens, and the vibrations in the tube room directly over the engine room were reduced materially by supporting the lines from the floor of the engine room instead of from the ceiling under the tube room."

This illustration has been selected from many others because it applies to an operation that all students can follow and not to any particular branch of engineering.

The connection that exists between motion and time study is indicated by the law of motion time which was evolved by Segur[1]—

Within practical limits, the times required by all expert workers to perform true fundamental motions are constant.

Motion study is essentially qualitative, while time study is quantitative; the savings made by the application of the former can be measured by the use of the latter. Such savings, however, could not be applied to more than one operator and a specific job, unless the law of motion time were true. There are two statements in this law that require further elucidation. Alford[2] says that by "practical limits" is meant those that usually surround the doing of work and motions taking longer than 0.0001 minute to complete. He also claims that this law is independent of sex, job, place, or condition. True fundamental motions are elements in a cycle of motions. Seventeen of these, including *search, find, select, grasp,* etc., have been classified by Gilbreth, and each of them is called a "therblig" (Gilbreth spelled backwards).

[1] *Manufacturing Industries,* November, 1926.
[2] Loc. cit., p. 412.

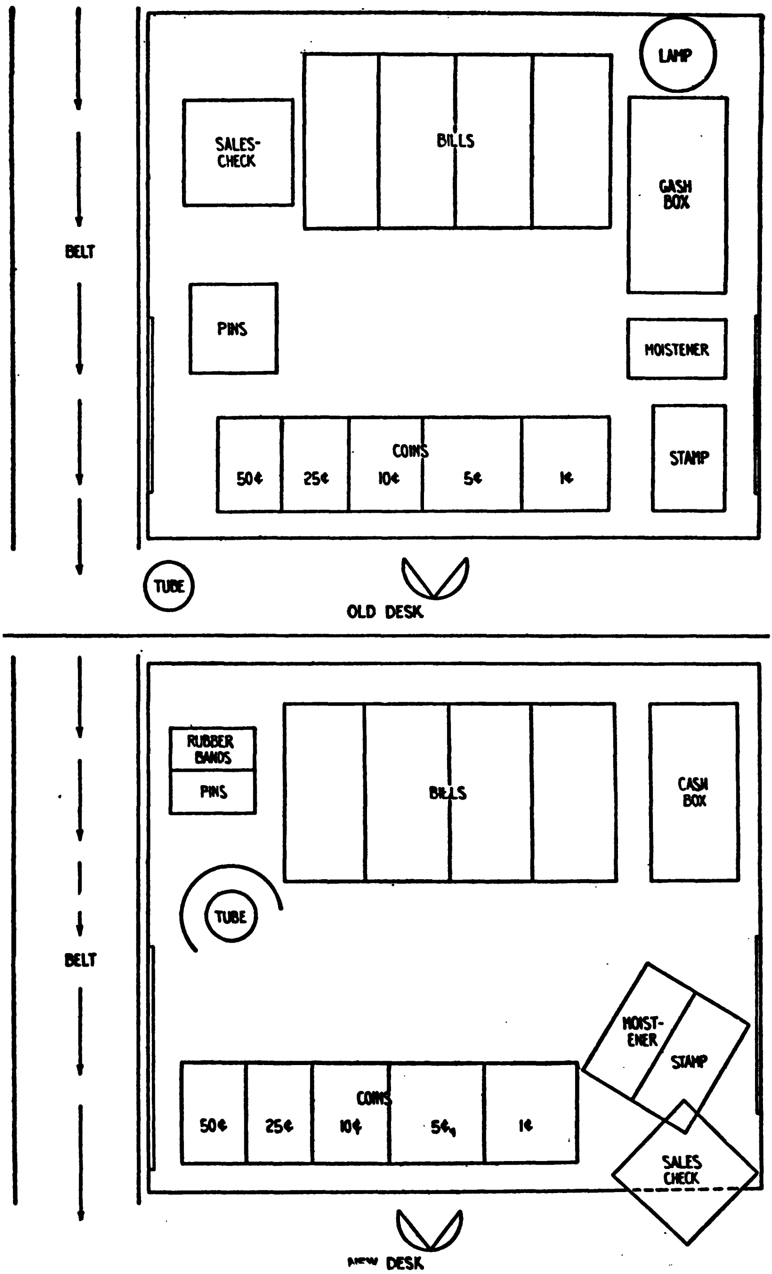


FIG. XII.2. OLD AND NEW ARRANGEMENTS OF CASHIER'S DESK

Standard symbols and colours have been devised for convenience in referring to these elemental motions, and these are used in motion study as a sort of industrial shorthand.[1]

Motion study usually applies to work done by persons, while time study refers both to men and machines.

Time study was originated by Dr. F. W. Taylor in the shops of the Midvale Steel Works, Philadelphia, for the purpose of fixing proper standards for a day's work. He realized that neither management nor foremen knew what was the possible output, their judgment being bounded by what had been done in the past rather than by present possibilities. As there was no incentive for a man to do his best, the pace of the shop was usually about that of the slowest worker.

Taylor first analysed the job into its elemental components, and then selected and synthesized the necessary ones to give a standard time, which formed the basis of the system of payment. The analytical and synthetic operations were described in his paper[2] as follows—

ANALYTICAL OPERATIONS

(*a*) Divide the work of a man performing any job into simple elementary movements.

(*b*) Pick out all useless movements and discard them.

(*c*) Study, one after another, just how each of several skilled workmen makes each elementary movement, and with the aid of a stopwatch select the quickest and best method of making each elementary movement known in the trade.

(*d*) Describe, record, and index each elementary movement, with its proper time, so that it can be quickly found.

(*e*) Study and record the percentage which must be added to the actual working time of a good workman to cover unavoidable delays, interruptions, and minor accidents, etc.

(*f*) Study and record the percentage which must be added to cover the newness of a good workman to a job, the first few times that he does it. (This percentage is quite large on jobs made up of a large number of different elements composing a long sequence infrequently repeated. This factor grows smaller, however, as the work consists of a smaller number of different elements in a sequence that is more frequently repeated.)

(*g*) Study and record the percentage of time that must be allowed for rest, and the intervals at which the rest must be taken, in order to offset physical fatigue.

SYNTHETIC OPERATIONS

(*h*) Add together into various groups such combinations of elementary movements as are frequently used in the same sequence in the

[1]See *Motion and Time Study*, Barnes, Chap. VI.

[2]*Trans. A.S.M.E.*, 1912.

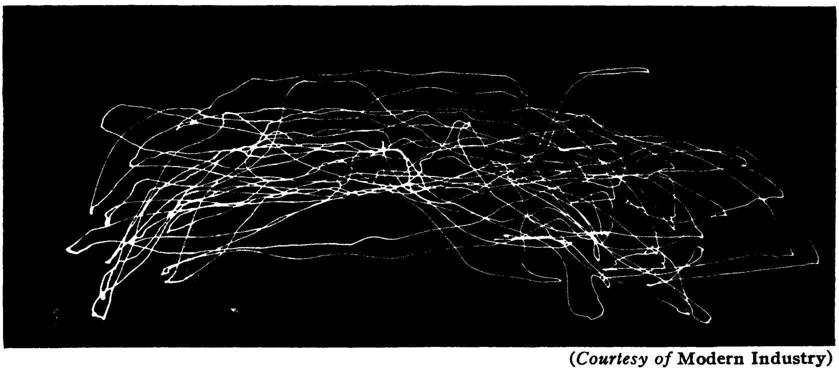
trade, and record and index these groups so that they can be easily found.

(*i*) From these several records it is comparatively easy to select the proper series of motions which should be used by a workman in making any particular article, and by summing the times of these movements, and adding proper percentage allowances, to find the proper time for doing almost any class of work.

(*j*) The analysis of a piece of work into its elements almost always reveals the fact that many of the conditions surrounding and accompanying the work are defective; for instance, that improper tools are used, that the machines used in connection with it need perfecting, and that the sanitary conditions are bad, etc., and knowledge so obtained leads frequently to constructive work of a high order, to the standardization of tools and conditions, to the invention of superior method and machines.

Certain principles have been laid down and confirmed by experiment to economize motion, time and effort.[1] They may be summarized as follows—

(*a*) *Eliminate unnecessary movements* of the worker by replacing hand by mechanical or foot movement, by using both hands or multiple controls, and by using gravity as far as possible.



(*Courtesy of* Modern Industry)

FIG. XII.3. HOW MANY MOVES TO PILE A STACK OF BOXES? IN THIS AUTHENTIC CAMERA STUDY, A BULB ON THE WORKER'S WRIST TRACES THE COMPLEX PATTERN OF HIS MOVEMENTS

(*b*) *Shorten and simplify all necessary movements* by keeping them within the normal working area for each hand, by removing barriers and by the proper arrangement of materials and products. Fig. XII.3. illustrates the movements of a worker's wrist when packing a stack of boxes, as recorded photographically from a light bulb on the man's wrist.

[1]See *Motion and Time Study*, Barnes, Chaps. XII–XIV; "Machine Design and Motion Economy," *Mechanical Engineering*, December, 1939; "Power and Velocity in Manual Work," *Mechanical Engineering*, May, 1940.

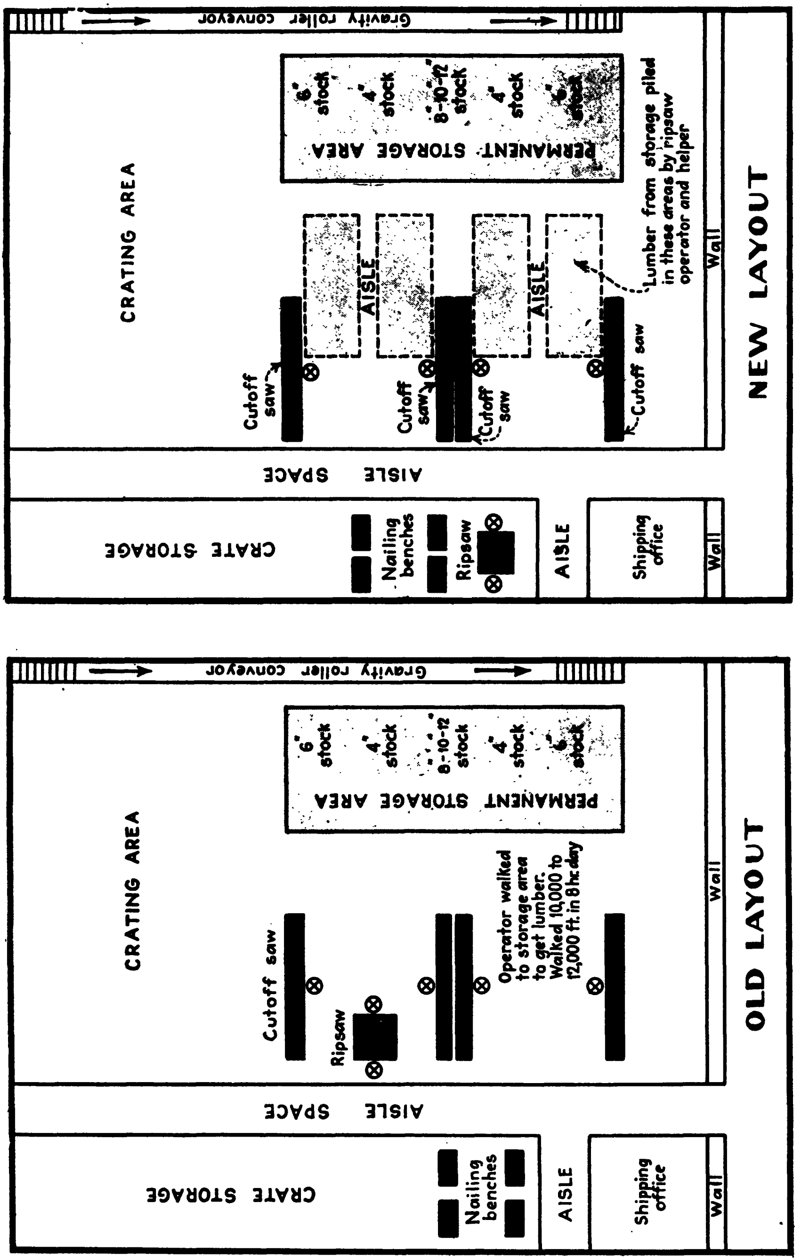


FIG. XII.4. LAYOUT OF A LUMBER YARD

(*c*) *Balance the work* by keeping both hands continually busy, as far as possible.

(*d*) *Minimize the use of eyes* by eliminating controls which are hard to find, by pre-positioning tools and materials and by reducing the areas to be watched.

(*e*) *Avoid using hands as holding devices* for work or machine parts.

(*f*) Use *momentum* to assist the worker and *rhythm* to give smooth performance.

The application of time study to industry enables standards of production to be set, checks the efficiency of men, machines, and operators, determines the best arrangement of men and machines[1] and facilitates payment by results. The importance of these factors indicates the need for great care and discrimination, both in making observations and in applying them.

Fig. XII.4. illustrates the change in layout of a lumber yard that reduced "walking distance" from two miles to 1800 feet per day and saved 30 per cent in the cost of cutting lumber.

Measurement of Time Elements.

The first operation is to make a complete survey of the job that is to be analysed. This includes not only an appraisal of the nature of the part and its functions, but also the facilities available for producing it, the kind of inspection to which it will be subjected, and the degree of standardization present. It is generally useless to set time values on an operation that is not continually being repeated in the same way, or in which the total expenditure involved is so small that the cost of making a time study would be greater than the possible saving that would result therefrom. If the cost of a detailed time or motion study is not warranted by the saving involved, the price is usually arrived at by estimate or by a short time study. Alternatively, payment by time may be used. When these points have been established, the next step is to choose the operator or operators whose work is to be studied. Other things being equal, it is preferable to observe a skilled operator, whose work will have a rhythm and consistency that will enable characteristic results to be obtained. In cases where similar work is being done by more than one man, it is desirable to observe several skilled workers. Times are taken by a stop-watch or watches, which are usually of the continuous variety and are graduated in decimal units. When the stop is pressed, the finger stops at the ending time of

[1]For examples, see *Common Sense Applied to Motion and Time Study*, by A. H. Mogensen (McGraw Hill Book Co.), Chap. XIV.

the operation, and then continues from this point when released, the elapsed times of individual motions being obtained by difference. Thus, motions Nos. 1, 3, 5, 7, etc., may be read for the first series, and 2, 4, 6, 8, etc., comprise the second. There is now a considerable tendency to return to the "snap-back" type of stop watch, as it is found that these observations can be taken, in most instances, with satisfactory accuracy and the subtraction of one reading from another is avoided by this means. Also, any departure from the normal range of figures is immediately apparent, so that the causes of such variations can be noted and recorded while the study is being made. Another method, used by Gilbreth, is to take a series of motion pictures, each of which includes a clock (Fig. XII.5.). This is particularly useful when motions are rapid, as the film may be run slowly through a projector and analysed at leisure.[1] The information obtained is recorded on an observation sheet, which may also contain particulars of the machine or operation (sometimes including a photograph), the conditions under which the work was done, the observer's estimate of the skill and effort required for the job, and the consistency of the worker. Speed indicators are also used in cases where cutting speeds and similar factors have to be measured.

The number of observations necessary depends on the nature of the job, and particularly upon the number of short elements involved. If there are many of these, the number of observations must be correspondingly great. Hand work is not so consistent as machine work, and therefore the difficulty of getting correct times is greater in the former case than in the latter, and more observations must be made. Standard practice for machine work is given by Anderson[2] as—

Time of Operation (Mins.)..........	.10	.50	1.0	10.0
Minimum No. of Observations......	600	120	60	6

It is recommended by most observers, that the number of studies made on short times should not be less than ten.

The "cycle" method is sometimes used for determining the times of short elements. It consists of taking a number of observations equal to the number of elements in the cycle, but omitting the time of one element in each case. Thus, if the cycle contained five elements, there would be five separate time

[1]See also *Common Sense Applied to Motion and Time Study*, Mogensen, Chaps. IX, XIII, and XVI.

[2] Loc. cit.

(*Courtesy of Factory and Industrial Management*)

FIG. XII.5(A). TAKING TIME STUDY WITH GILBRETH CLOCK AND MOVING PICTURE CAMERA

(*Courtesy of Factory and Industrial Management*)

FIG. XII.5(B). ENLARGEMENT OF FILM TAKEN AS IN FIG. XII.5(A)

measurements omitting respectively the times of elements 2, 3, 4, 5, and 1. Thus the sum of all the times is four times that of the complete cycle, and successive elemental times can be obtained by difference from respective observations.

Electric time meters are also available for indicating the length of time that any machine actually operates. Mogensen[1] describes how an installation of time meters paid for itself in a few weeks by reducing claims for idle time compensation. He also describes another case where the purchase of an expensive new machine was avoided, by proving that the existing machine was working for a very short total time in each day.

Standard Time or Performance.

A preliminary study is usually made to familiarize the observer with the job and the conditions of work, but after the elemental times have been obtained from the observation sheet, the next procedure is to combine them in such a way as to give the standard time in which the work should be done by a normal, experienced operator. This is sometimes called the "*selected operation time*," and does not include allowances for fatigue and other delays that will occur with an ordinary operator. Having discarded abnormal times from the study, a correction factor may be applied to the actual recorded times. The actual times may be low, or high, depending on various factors such as ability, fatigue, co-operation or lack of concentration. An experienced observer can relate these factors fairly closely to the performance of the actual operator as compared with a normal operator.[2] A method that has been widely used is the rating of effort. This consists of applying rating factors to a sufficient number of actual element times, thus relating actual times to expected times for standard performance. For example, a series of times of 0.10 minutes may be rated at 20 per cent above standard, some at 0.08 minutes at 50 per cent above standard, and some at 0.12 minutes as standard. The allowed time is then 0.12 minutes.

Abnormal times should not be included when computing the selected time. There are a number of different methods used for obtaining this time.

1. AVERAGE METHOD. This is the simplest and most obvious

[1]Loc. cit.

[2]See *Dynamics of Time Study*, by Ralph Presgrave (McGraw-Hill) and *Time Study Methods and Job Evaluation* by Phil Carroll, Jr. and A. L. Kress, American Foundrymen's Association, Management Series, No. 11-1941.

method, and consists of adding together the averages of the elemental times. It is not always advisable, however, as it usually gives a high figure which is not representative. This is due to the fact that the average includes high times, which are subsequently compensated for when the allowances are added.

2. MINIMUM METHOD. This consists of adding together all of the minimum elemental times. It is infrequently used, as it is severe and unfair unless liberal allowances are made. As the allowances are largely matters of experience and discretion, it is unwise to leave too much to be added in this way.

3. MODAL METHOD. This consists of averaging the most frequently recurring times in each observation, and adding together the elemental times thus obtained. It usually gives a time somewhere between methods 1 and 2, and one writer comments as follows:—

As for the statistical analysis of data, it is not felt that more accurate methods are needed than the simple ones now at our disposal. Determinations are made for (*a*) the selected minimum, (*b*) lowest third, (*c*) mode or modal average, (*d*) median, (*e*) selected average, and (*f*) the arithmetic average. Which of these is used in the establishment of a standard depends upon the point of view of the analyst. Their use in turn affects the amount of allowance to be applied. For instance, a much higher percentage allowance must be applied to the selected minimum than the average. What we need is a more common use of the statistical method which would result in the most representative measure of the operator's performance. Investigation by the writer into the relative values of these various statistical methods has led to the adoption of the mode, or modal average, as the simplest means that would yield the most representative results. The modal average, being the value about which most cases recur, is the most reliable method of determining the characteristic or typical performance of an operator. This determination is made possible with relatively few observations as compared with the number that are required when using the method of averaging.

In this connection the writer would like to present for consideration a few facts pointing to the degree of credibility which may be placed upon the modal-average method. What the writer has in mind is the time required to perform an element of a weaving operation in the silk-textile industry. On the basis of slightly over 1000 observations made in approximately 20 silk

and rayon mills, the modal average was 0.098 min. Adding to these about 7000 more observations, the modal average was still 0.098, while the arithmetic average dropped from 0.124 to 0.108, or 12.9 per cent. It is interesting to note that the arithmetic average, becoming more representative as the number of observations is increased, approached the modal average to a point within 0.01 min. when the quantity of data was increased sevenfold.

Taking at random the observations made on one weaver during one study period, the modal average was 0.116 on the basis of 46 occurrences. When this study was extended to 262 occurrences, the modal average was 0.115 or a change of 0.9 per cent, while the average increased 5.6 per cent. It appears from these data that the modal-average method yields the most consistent results.[1]

4. LEVELLING METHOD.[2] This consists of multiplying the average times obtained by method 1 by a levelling factor, which takes into account four things, namely, skill, effort, conditions, and consistency. These factors are estimated by the time study man, and the levelling factor is obtained from a series of tables or curves.

Thus, if L is the levelling factor, S the standard time per piece, and T the actual or observed time per piece

$$S = T \times L$$

Other methods are used in specific cases to obtain the overall time of the job, but the above examples serve to indicate the general idea.[3]

Allowances.

The times thus obtained are those of a normal, experienced operator working at a fairly slow speed. They do not allow for unusual delays and other legitimate allowances. So far, the procedure may be termed scientific, but the allowances made, which may be as great as the selected operation times, are based on judgment and experience, and therefore are not so accurate. Some allowances, such as those for fatigue, are fairly constant for various classes of work, and may be made by adding a flat percentage to the allowed time, but others are special or variable.

[1] *Trans. A.S.M.E.*, October, 1940, p. 591.

[2] See *Time and Motion Study*, Lowry, Maynard & Stegemerten, Chaps. XII, XIII.

[3] See also "Effort Rating," Ralph Presgrave, *Advanced Management*, Vol. IV, No. 5 (1939).

(*a*) FATIGUE ALLOWANCE. It is impossible for an operator to work continuously at the rate indicated by the time study. Therefore the conditions of work must be adjusted so as to reduce to a minimum the drop of production that is likely to take place toward the end of the working period. Lighting, temperature, ventilation, humidity and posture must be arranged to give the maximum of comfort. Several firms now specialize in air-conditioning apparatus for this purpose. When these conditions have been adjusted, the allowance for fatigue will depend on the nature of the work, the physique of the worker, and the length of the operating cycle or period.

Fatigue is caused by an accumulation of poisonous waste matter in the system, and the rest periods must be sufficient to allow the body to recuperate between the working periods. When sustained effort is accompanied by speed, the effect is likely to be cumulative, as in the case of pieceworkers who are straining every nerve to complete a given task every day. Long machine operations give natural rest periods while the machine is doing the work, but short processes in which the human element plays a greater part must be broken up by suitable rest periods. In one case, the machine operators were allowed to fetch their own material instead of having it brought to them, thus having a change of occupation during that time. In other cases, definite rest periods of ten minutes were scheduled during the morning and afternoon of each day, with a consequent increase of production. As indicated above, monotony is a prevalent cause of fatigue. It must be counteracted by some change of activity.

This factor is particularly important with women workers. A report of the Industrial Fatigue Research Board (England, 1919), states that "where the hours are abnormally long, the workers have effectively protected themselves up to a certain point by bad time-keeping, and more or less regular taking of days off apart from absence caused by sickness, and they have done this, not from laziness, but from physiological self-protection."

The regular allowance for fatigue varies from 3 to 7 per cent, but for severe hand work an allowance varying from 10 to 20 per cent is sometimes used.

(*b*) PERSONAL ALLOWANCES. These vary with the individual rather than with the nature of the work, and so an average must

be arrived at for the shop. From 2 to 3 per cent of the standard time is usually allowed for this purpose.

(*c*) Delay Allowances. These consist of time lost due to changing from one job to another, minor adjustments to machines, changing tools, receiving instructions, and other unavoidable delays that are not included in the time study or in the other allowances. Machine delays are expressed in terms of machining time, they may vary from 5 to 10 per cent on a power-feed machine, or up to 20 per cent on a hand-feed machine. In some cases, this allowance is so small that it is included in the fatigue allowance.

When the waiting time is long, instead of an allowance on the piece-time, a special day-work time slip is sometimes used to cover the period. Excessive delays of this kind indicate the advisability of a change in the arrangement or conditions of work.

(*d*) Preparation or Set-up Time. This is the time required for setting up the tools or preparing for the job. It may be small on a simple machine, but is frequently considerable on an automatic machine. The time absorbed in getting instructions, taking down the preceding set-up and arranging and adjusting the new one, can be analysed as a separate operation, and standard times may be calculated by the methods already described. Alternatively, it may be spread over the quantity of articles made on the machine, but in that case, the time to be added to each component will vary with the number of pieces made. This additional time may be tabulated for various lot sizes, but such a procedure complicates the costing process. With new jobs, this is sometimes amplified by an allowance for the extra time taken in making the first piece or pieces after the new set-up. It is a well-known fact that unanticipated difficulties usually appear at the beginning of a new job, and the output is less because the worker is unfamiliar with it. In other instances, this extra time is absorbed in the overhead expense, so that the cost records may be made simpler.

(*e*) Special Allowances. Where special difficulties occur, due to the unusual size, weight, or quality of material, or to the enforced use of non-standard equipment for rush jobs, it is necessary to make special allowances in addition to those outlined above. These will naturally vary with the particular circumstances, but in some instances it is preferable to deal with

TIME STUDY OBSERVATION SHEET

Form 247 H

MASSEY-HARRIS CO., Limited — No. 2 Machine Department

Tool and Type Machine: 4-Spindle Drill	Machine No. 22-G	Machine Speed 160 R.P.M. Feed .031 P.R.
Part or Assy No. GA-642	Description of Part or Assy: Bracket for Worm on Upper Shaft	Machine Used on: No. 9 R.T.
Date of Study: May 28/28	Taken by: H B Johnston · Checked by: RM.	Authorized by: AH

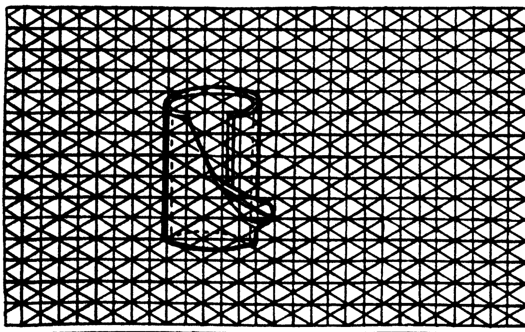
Note—All Times to be shown in Decimals of Minutes. All Dimensions to be shown in Inches. P.W. Prices to be shown only in Decimals. No Fractions to be used.

	No. of Pieces	1	2	3	4	5	6	Total
	1	.17	.55	.24				
	1	.18	.55	.29				
	1	.16	.55	.19				
	1	.19	.55	.26				
	1	.17	.55	.22				
1. Handling Time								
2. Ream 1 hole 15/16" x 1 1/2"								
3. Idling Time								
Vize Jig	5	.87	2.75	1.20				
Average Time	1	.174	.55	.24				.964
Selected Time								
Corrected ___ %								
Allowance at Detailed 33								.321
Total Time	1							1.285

Observers Remarks—

Allowance—

SET UP—Included / Not included in P.W. Price of Operation



Kind or Class of Material: Malleable	Length of Bar · Weight of Bar
Size of Piece	Length of Piece: 1 1/2" · Weight of Piece
Standard Operation Name as in P.W. Book: 4-Spindle Ream 1 hole 15/16"	
Previous Operation: Punch Hole 7/32	Operation Following: 4-Spindle Drill 2 Holes 3/16
No. of Men: 1 · Operator's Name and No.: Funston - 138	Production per Hour: 46
Rate per Hour: .45	P.W. Price per 100: .24
Displaced Operation of Time: New	Part or Ass'y No. GA-642

Recommendation.

Fig. XII.6.

did other European countries, Austria and France in

this situation by doing the work on a day-work basis rather than by means of a special allowance.

The allowance itself may be determined by taking a long motion study under working conditions.

The Allowed Time or Task Time.

The standard or selected operation time plus the allowances that have been made give the average time in which the job may reasonably be expected to be done, and this is the basis for rate fixing. Figs. XII.6-10. give examples of observation sheets or work studies that are used in industry. Fig. XII.6. relates to a drilling operation in which the average method of selection is used and 33 per cent is added for allowance. A diagram of the part is sketched in perspective form. This is convenient for the purpose of identification. Figs. XII.7. and 8. illustrate the use of "effort rating" on a glass cutting operation in which the work of one operator controls the rate of the other. The rating factor in each series of operations is placed above the recorded series of times. The fatigue allowance (8 per cent) and personal allowance (2 per cent) is added to the total time in each case. Fig. XII.9. is a similar study for a machining operation in which the cycle is controlled by the speed of the machine and, as the job percentage is less than 50 per cent it is concluded that the operator should run at least two machines. The fatigue allowance here is 5 per cent. Fig. XII.10. is a study of a grinding operation on a small part in which the times are very short. The fatigue allowance in this case is 10 per cent.

Operation or instruction sheets may then be drawn up, as indicated in Chapter VI, which may replace or supplement a drawing for the purpose of teaching the workman the best way of doing the job. This gives in detail the various operations to be performed, their order, the feeds and speeds to be used, and, in some cases, the standard jigs, tools, and gauges to be employed.

Curves and Formulae.

Standardization of equipment and manufacturing processes reduces the number of variables in time study work, particularly where machines are concerned, and makes it possible to generalize to some extent. The results of existing time studies can thus be applied to new jobs without the necessity of making special studies, which, by reason of the time and expense involved, would be impracticable. A master table of time studies, the results of which have been checked by previous experience,

WORK STUDY

DEPT. Glass cutting DATE 12 November 1946 SHEET 2 OF 2

OPERATION Break (see cut study) OPERATOR J. Jones

DATA #1200049 Windshield - 1/8" plate - sheet 14" x 26"

FINISH 2.49	DISALLOW 4.14 idle	EST. RATING 35	QTY. 48
START 2.32	ELAPSED 12.85	ACTUAL RATING 32	OBSERVER B.C.

STD. TIME 43.0/100 APPROVED

ITEM		1	2	3	4	5	6	7	8	9	10	11	12	S.A	S.R.	SUMMARY	VALUE
1	P/u from machine Rating factor	15	13	14	35 15	15	16	15	15	50 13	15	17	14	15	35	15 x 1.35	20.3
	Break - 1 piece	15	17	14	14	15	35 15	15	14	16	15	15	16				
	Dispose scrap to barrel	14	16	15	30 15	15	13	18	15	15	25 18	15	15				
		14	14	15	15	13	14	15	35 15	16	40 12	13	15				
2	Dispose pc. to truck	10	11	10	40 10	11	12	10	10	11	35 11	11	10				
		11	30 11	12	10	10	11	30 11	10	11	40 10	11	12	11	30	11x1.30	14.3
		14	10	11	11	10	20 12	12	11	30 11	11	10	11				
		11	11	13	12	40 10	10	30 11	11	12	13	10	11				
3	Shift truck	82		per	100	pcs.								82		82/100	.008
4	Wait for cutter	8	9	10	8	8	8	7	9	10	7	10	10				
		8	9	7	8	10	11	10	10	11	8	8	7	See		"cutter	
		8	8	9	8	10	9	11	8	7	9	10	7				
		8	11	7	8	8	8	7	8	9	10	7	8				

13 ~~||||~~	10 ~~||||~~ ~~||||~~ ~~||||~~ |	TOTAL	354
14 ~~||||~~ ~~||||~~	11 ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ |	F.A. % 8	AUX % 2
15 ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ |||	12 ~~||||~~ ||	TOTAL PER	.390
16 ~~||||~~ |	13 ||		
17 ||			
18 |			

Note: Cutter's rate of .430 controls the operation
Operation cannot be adjusted more evenly
Pay same rate as cutter

(*Courtesy of J. D. Woods & Gordon Limited*)

FIG. XII.7.

WORK STUDY

DEPT Glass Cutting DATE 12 November 1946 SHEET 1 OF 2

OPERATION Cut (see "break" study) OPERATOR M. Smith

DATA Glass cutting machines

#1200049 - Windshield - 1/8" plate - sheet 14" x 26"

FINISH 10.34½ DISALLOW . EST RATING 10 QTY 35

START 10.21½ ELAPSED 12¾ min. ACTUAL RATING 8 OBSERVER BC STD TIME 43.0/100 APPROVED

ITEM		1	2	3	4	5	6	7	8	9	10	11	12	S A	S R.	SUMMARY	VALUE
	Rating factor ⟶		20					10			15		std				
1	Slide cut sheet to helpers	28	26	28	27	28	30	28	27	30	28	26	29	28	10	28 x 1.10	.308
	P/u next sheet - place in	29	28	10 28	28	30	x 37	28	27	27	10 28	28	29				
	Machine to stops - up table	27	29	28	10 28	28	std. 30	26	28	10 28	27	28					
2	Cut - 3 sides	5	6	6	5	7	6	10 6	6	6	10 6	25 5	6	6	10	06 x 1.10	.066
	- length 63½"	5	7	10 6	6	6	20 5	7	6	7	std. 6	5	6				
		6	6	5	8	6	6	10 6	std. 7	5	6	6					
											12						
3	Brush chips from table								20 12					10	std	1/10x10x1.00	.010
								std. 10									
4	Shift truck of glass																
	to position	.67		-		per	100	sheets						67	std	1/100x .67	.007
	x sheets stick together																

26 111 5 ~~1111~~ 111

27 ~~1111~~ 1 6 ~~1111~~ ~~1111~~ ~~1111~~ ~~1111~~ 1

28 ~~1111~~ ~~1111~~ ~~1111~~ 11 7 ~~1111~~

29 1111 8 1

30 1111

TOTAL .391

F A % 8 AUX % 2

TOTAL PER .430

(*Courtesy of J. D. Woods & Gordon Limited*)

FIG. XII.8.

WORK STUDY

DEPT Machine Shop DATE 12 November 1946 SHEET 1 OF 1

OPERATION Drill 1 hole - 3/8" x 1" OPERATOR J. Doe

DATA Bracket - Grey iron Weight 3 lbs.

Swing top jig - Held by 1 cam. - speed 1,000 r.p.m.

FINISH 1.33	DISALLOW	EST RATING 25	QTY 35			
START 1.15½	ELAPSED 17.75	ACTUAL RATING 25	OBSERVER B.C	STD TIME 68.0/100	APPROVED	

ITEM		1	2	3	4	5	6	7	8	9	10	11	12	S A	S R.	SUMMARY	VALUE
	~~Rating factor~~				25		25		x		25		20				
1	P/u from truck at left	12	12	13	12	12	11	11	18	12	12	11	13	12	25	12 x 1.25	.150
	Place in jig	12	25 12	x 19	12	12	10	14	12	30 11	11	20 12	12				
	Tighten	12	11	13	13	x 19	25 12	12	12	13	25 12	12					
	Start feed																
2	Drill 1 hole *	28	28	28	28	28	28	28	28	29	28	28	28	28	25	28 x 1.25	.350
	Automatic feed *	28	28	28	28	28	28	28	28	28	28	28	27				
	*	28	28	28	28	28	28	28	28	28	28	28		Machine controlled			
														Use rating of 25%			
3	Up drill - loosen jig	10	10	9	11	9	25 10	10	10	11	25 10	10	30 10	10	25	10 x 1.25	.125
	remove part to truck	9	11	10	10	10	30 11	10	10	25 10	11	11	9				
	at right	10	10	20 11	9	10	25 10	11	10	10	11	25 10					
	x Brush chips allowed	- allow (19-12)												7	25	1/10x7x1.25	.009

10 1	9 ~~1111~~	TOTAL	634
11 ~~1111~~ 1	10 ~~1111~~ ~~1111~~ ~~1111~~ ~~1111~~ 1		
12 ~~1111~~ ~~1111~~ ~~1111~~ 1111	11 ~~1111~~ 1111	F.A. % 5	AUX %2
13 ~~1111~~			
14 1		TOTAL PER	.678

Standard is based on 25 to 35% bonus opportunity
If work is done at 30% above standard, expected cycle is
$\frac{.284}{1.30} + .28$ or .218 + .28 or .498

Job percentage = $\frac{.218}{.498}$ = 44% Operator should run at least 2 machines

* Constant time factor due to machine

(*Courtesy of J. D. Woods & Gordon Limited*)

FIG. XII.9.

WORK STUDY

DEPT	Plastic Finishing	DATE 12 November 1946	SHEET 1 OF 1
OPERATION	Grind flash	OPERATOR	J. Doe
DATA	Pin		

FINISH	9.39	DISALLOW	.42	EST RATING	25	QTY	165	
START	9.31¼	ELAPSED	7.33	ACTUAL RATING	23	OBSERVER	B.C	STD TIME 6.5 per 100 APPROVED

ITEM		1	2	3	4	5	6	7	8	9	10	11	12	S A	S R	SUMMARY	VALUE
	Rating factor →		35				25				25	30					
1	Pick up from tray	23	21	23	24	21	23	25	28	23	23	22	24	23	25	$\frac{23}{5}$ x 1.25	.0575
	Place in air chuck	21	23	30 25	23	25 23	23	22	23	22	24	25 23	23				
	Move grinding wheel to part	23	22	30 22	23	25 23	25	21	23	23							
	-Grind																
	-Disposed by air																
	Studied in groups of 5 pcs/																
2	Fill tray from truck					.42		for	1,000		pcs.						.0004

21 1111		TOTAL	.0579
22 ~~1111~~	.21 rated @ 35)		
23 ~~1111~~ ~~1111~~ ~~1111~~ 1	.22 " @ 30) select .23 @ 25	F A % 10	AUX % 2
24 111	.23 " @ 25)		
25 111	.25 " @ 10)	TOTAL PER	.065
26			
27			
28 1 - fumble			

(Courtesy of J. D. Woods & Gordon Limited)

FIG. XII.10.

may be drawn up as a basis for these formulae, and each individual element classed as constant or variable. The details of this process, together with a number of examples, are given by Lowry, Maynard & Stegemerten.[1] They are too lengthy to be given here, but the process is similar to that used in determining formulae for other scientific operations.

The important points are, to establish the field of the formula, so that it will not be used in cases where it does not apply, and the correct relationship of the different variables. This done, the formula may be expressed in the form of tables, curves, or nomograms, the choice being dictated by convenience. Wherever possible, the formula must be checked by existing time values, and revised when conditions change in such a way as to make revision necessary.

Personnel.

From the previous paragraphs, it is evident that the successful application of motion and time study depends largely on the personalities of the men who apply it. The observers must not only be competent, but must have a considerable amount of tact and judgment. Any man who tries to introduce new methods in a workshop will meet with the opposition, open or concealed, of the men who are working there. This conservatism is accentuated when the scheme affects questions of payment, as the men feel that it is simply a device to make them work harder for the same or less pay. The observer, therefore, must by his personal contact with the men do his utmost to dissipate that suspicion, which will be particularly marked in cases where secrecy or mystery are prevalent. The study should be made openly, after an explanation of its nature and expected benefits. Confidence and co-operation are absolutely necessary for success.

In addition, patience is an important attribute in the face of opposition and non-co-operation, but this should not be the result of weakness, as self-confidence is necessary in situations where judgment has to be applied. A reasonable degree of education is required to enable the time study man to understand curves, formulae, and drawings, while an analytical mind is advantageous in a process such as this which is of a distinctly analytical nature. Shop experience also is desirable, so that the various factors comprising a job may be correctly understood and evaluated. It is impossible, of course, to get all of these qualities in a single man, but a combination of as many of them as possible should be looked for in men engaged in this work.

[1] *Time and Motion Study*, Chaps. XVIII–XXXIII.

Results of Time and Motion Study.

Shields[1] expresses a fairly general view when he says: "It is somewhat difficult, even in the cases cited by scientific management writers, to determine to what extent the successful results have been due to time study supplemented by rest pauses, to a reduction in working hours that generally accompanied it, or to the inducement of increased remuneration by means of a new bonus or premium system, or to a combination of a number or all of these factors. In all probability they all contributed to the success of the system, but the influence of the separate factors has not been noted."

Also, with reference to the large number of variables classified by Gilbreth, he remarks:[2] "Gilbreth rather overloads the task of the most skilful and scientifically-brained industrial specialist. If all these factors have to be taken into account in conjunction with the fact that individual workers vary in mental capabilities and physical energy, the investigation of the subject would become almost impracticable to most of those engaged in the experiments."

The subject has suffered somewhat from the enthusiasm of its friends, and particularly from the over-indulgence in analysis of some writers, which has made it unnecessarily complicated. Many of the variables mentioned must be ignored or merged into averages which can be applied over a wide range. Marked exceptions must be treated as such. With the above proviso, however, there is considerable evidence to show that the application of time and motion study has effected considerable savings, apart from its convenience in defining a fair day's work. The following are some examples of this—

	Increased Production per Worker per Cent	Increase of Individual Earnings per Cent	Reduction of Labour Cost per Cent
Making Concrete Slabs[3]	400	100	62
Cleaning Castings[3]	144	35	45
Removing Gum Tape[3]	400	67	67
Storeroom[3]	88	25	34
Crating[3]	400	108	58
Band Saws[3]	200	70	43
Cashier's Work[4]	26	88 (bonus)	—
Handling Pig Iron[5]	380	63	64
Lathe Work[5]	100	40	41
Inspection[5]	370	86–100	45

[1] *The Evolution of Industrial Organization*, p. 109.
[2] Loc. cit., p. 113.
[3] Lowry, Maynard & Stegemerten.
[4] Leis & Sealy.
[5] F. W. Taylor.

Attitude of Labour.

Until quite recently, labour generally and trade unions in particular, have been antagonistic to the idea of motion and time study. In 1934 a group of workers in England applied for an injunction to restrain their employers from using experts who sought to speed "the ancient and noble craft of wire drawing . . . standing above us with note books and stop watches, almost breathing down our necks." They alleged that using these methods constituted a breach of contract.

There is some evidence that this attitude is changing. The following is taken from "Labour's Attitude Towards Time and Motion Study," by Spencer Miller, Jr., Secretary and Director of the Workers' Educational Bureau. (Excerpt from "*Mechanical Engineering*, April, 1938, p. 290)—

> . . . The most insistent objection by a majority of the unions to the use of time study is thus concerned more with the *method* than with the *principle*. Time study should be a scientific method of measuring human effort and productivity in terms of time. In many instances, however, time-study methods and their results have been imposed arbitrarily on workers by management, with little regard either to the consent of the worker or the right of joint review. Also, little recognition has been given to the fact that it is the *worker's* job and health, indeed his very *life*, that will be affected. For this reason, he should be consulted and protected in his relation to changes. While the principle of joint conference and mutual consent in such procedure is a comparatively recent development, it can no longer be ignored today by either group. The importance of such a procedure has been abundantly proved. In those cases where time study has been conducted most successfully in union shops, the time-study method and its objectives have been carefully explained to the union and the workers in advance, and both consent and co-operation have been secured from labour as a result of conference and discussion.

One method of familiarizing the employees with this idea is described in a resumé of papers on "Current Problems of Management," read at the 1937 A.S.M.E. Annual Meeting. (Excerpt from *Mechanical Engineering*, January, 1938, p. 84)—

> . . . Training employees and supervisors in work simplification and, finally, in time and motion study, was described by George Dierstein, Duncan Electric Manufacturing Co. The plan was worked out by Mr. Dierstein and put into operation in a plant employing about 350 employees. Over a period of a year and a half, a group of employees representing about 20 per cent of all the workers was given a thorough training in work simplification with the aid of motion pictures, charts, actual problems selected from the plant, and general

discussions. As soon as the group had realized the energy, time, space and materials being wasted in their own plant, the fundamentals of time and motion study were explained to them. From this point on, with the group disseminating to others what it had learned, it was quite simple to sell time and motion study to all the employees. The group conference method is still continued by the company with much success in settling problems.

CHAPTER XIII

INSPECTION[1]

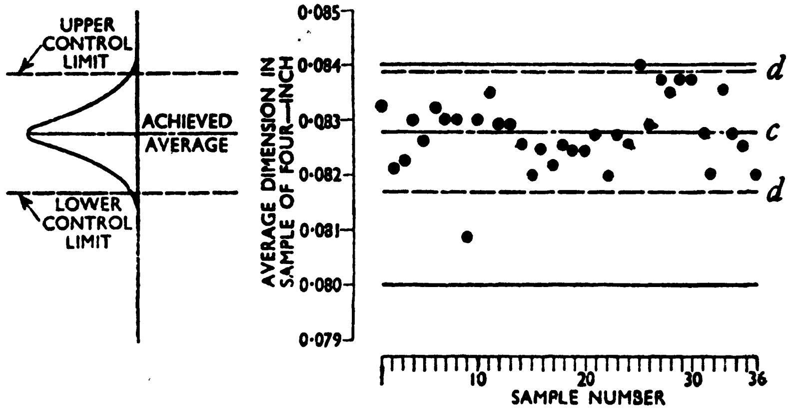
General.

The importance of standards in engineering practice and the various kinds of standard used have already been considered in Chapter II, but the usefulness of these in practice depends on the method of attaining them. Inspection may be defined as the comparison of materials, products and performances with fixed standards, and as mathematical exactitude is impossible, it also implies the existence of allowable variations therefrom. The closer the limits prescribed for the work the higher will be its cost, and therefore the variations allowed by the designer must be sufficiently wide to permit the work to be done economically without impairing the usefulness or appearance of the product. Graeper[2] states that: "There are two contending forces that influence the inspector. The one comes from the outside, in the form of complaints by customers and from the sales organization, which normally is a booster for higher quality, to meet and overcome sales resistance arising from this factor. The other comes from inside the factory walls and arises from the struggle to keep down costs. It is particularly strong when manufacturing difficulties arise, when rejections mean retarded deliveries, scrapped parts or heavy losses. The quality of the same, or similar product made by the competition, becomes a component of one or the other of these forces. The direction in which it is effective depends upon whether this quality is higher or lower than that of the product with which it is being compared."

The standard of quality that results from this conflict of interests is a compromise, which depends on the kind of market to be supplied and the degree of safety required in the product (see Chapter II). In the case of aircraft or other similar work, where safety is an essential factor, the inspection must be correspondingly rigid, and precision work comes within the same category. The manufacture of articles such as furniture, however, depends on fashions and appearance, so that the inspection arrangements will be different in this and other similar fields.

[1]See also *Engineering Inspection*, by Allcut & King (Routledge).
[2]*Trans. A.S.M.E.*, January–April, 1928, Paper No. MAN, 50–7.

Articles made in small quantities do not require the same inspection procedure as those made by mass production methods, as, in the latter case, much money may be lost by errors which may appear during the manufacturing processes. It is important to discover these at an early stage so that spoilage of large quantities of material may be prevented.



(*Courtesy of Institution of Mechanical Engineers*)

FIG. XIII.1. STATISTICAL QUALITY CONTROL DIAGRAM

Statistical Quality Control.

A method of approaching the problem of quality control that has grown rapidly in importance during the past ten years is called "Statistical Quality Control" or "S.Q.C." Many books and papers have been written about it[1] and societies have been organized to study its principles and applications.

The following excerpts are taken from a paper on this subject by Dr. A. E. R. Westman of the Ontario Research Foundation—

It is distinguished from other methods in that it involves the application of ideas derived from mathematical statistics and uses simplified statistical methods of calculation in achieving the objectives desired. However, this approach to the problem of quality control is so fundamental in character, that practically all other methods of quality control will be found in practice to fit into a statistical quality control scheme without very much modification, so that once statistical quality control is introduced into a manufacturing organization it tends to become a unifying agency for all quality control efforts.

[1]See "Economic Control of Quality of Manufactured Product" (W. A. Shewhart), *Mechanical Engineering*, December, 1934; July, 1938; June, 1940; May, 1942. Symposium of Papers on Quality Control (*Jrl. I. Mech. E.*, December, 1943). Discussion on the Application of S.Q.C. (*Jrl. I. Mech. E.*, June, 1942). "Guide for Quality Control and Control Chart Method" (*American Standards Association*, May, 1941, and April, 1942). "Statistical Quality Control" (A. E. R. Westman), *Manufacturing and Industrial Engineering*, October, 1945–March, 1947.

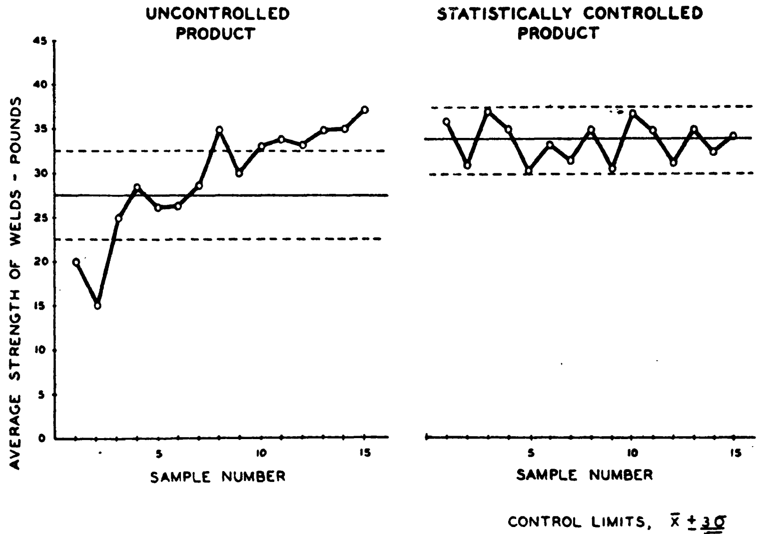
The statistical method implies that a satisfactory basis of control can be established by suitable methods using a number of measurements or inspecting a number of articles. The conclusions reached cannot be specific regarding any one article but will give the probabilities relating to a group of articles or the general run of the product. It involves the calculation by mathematical methods of the "risks" and "chances" involved in a manufacturing situation and substitutes quantitative estimates and calculations based on adequate data for the guesswork that is usual in sampling inspection.

The historical development of the ideas embodied in statistical quality control shows its close relation to modern industry. Before the industrial revolution and when manufacturing was largely an art, individual attention was given to each article produced and thus a high level of quality, but not necessarily uniformity, could be maintained. With the introduction of mass production and the interchangeability of parts, individual attention was economically impossible but a high and uniform level of quality very desirable. It is surprising that it was not until the late 1920's that the full implications of this problem were realized, and a group of engineers in the United States under the leadership of Dr. W. A. Shewhart of the Bell Telephone Laboratories developed the first and in many ways the most useful methods of statistical quality control.

Various bodies such as the American Standards Association, U.S. Army Ordnance and the Office of Production Research and Development in the United States and groups in Army Ordnance and in the Ministry of Supply in Great Britain undertook the job of promoting the use of statistical quality control in the war industries. In Canada there was no official body assigned to the task but the Bureau of Mines at Ottawa and the Ontario Research Foundation at Toronto have been active in this field. That the results obtained have been very striking is shown by the growing interest in the subject and the numerous articles published in the engineering literature.

The main objective is to improve the uniformity of the product and to get information of impending trouble as far in advance as possible. A probability curve is drawn from the frequency distribution of the qualities or dimensions obtained and this enables a diagram to be prepared as in Fig. XIII.1. in which the upper and lower control limits are between the upper and lower tolerance (or permitted) limits as shown by the full horizontal lines above and below d.d. If the plotted points keep consistently between the control limits the product is said to be "in control." If it fluctuates violently beyond the limits it is "out of control" (Fig. XIII.2), but before this point is reached there are frequently danger signs to indicate that the product is

about to pass beyond the limits. The use of the control chart to indicate its use as a guide to action is shown in Fig. XIII.3.



(*Courtesy of* Mechanical Engineering)

FIG. XIII.2. PRODUCT "IN AND OUT OF CONTROL"

Laws and Objectives.

The laws of inspection are given by Alford[1] as follows—

1. *The quality of manufactured goods is a variable with an upward trend under conditions of competitive manufacture.*

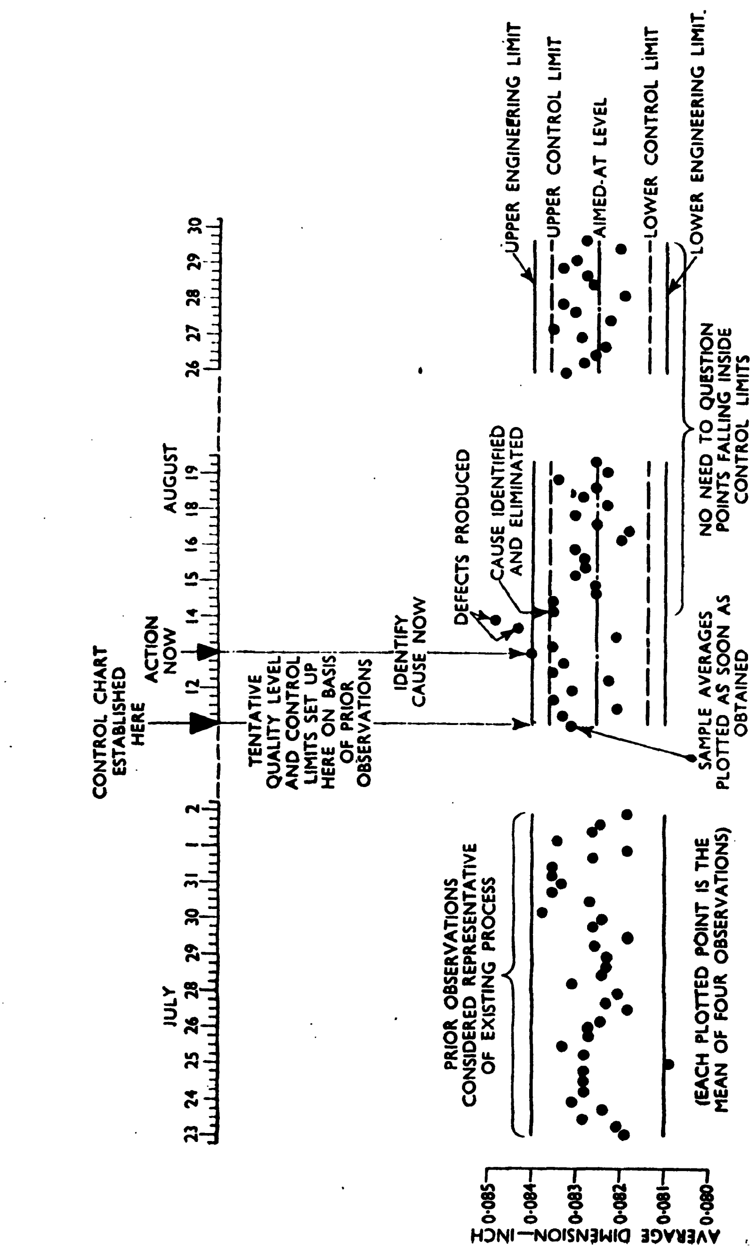
2. *Control of quality increases output of saleable goods, decreases costs of production and distribution, and makes economic mass production possible.*

3. *The inspection function in manufacturing for highest efficiency, must be independent of, but co-ordinate with, the functions of engineering, production, and sales.*

The first of these laws indicates the tendency of competition to improve the quality of manufactured goods. Other things being equal, the best articles have the greatest sale.

The second law may seem strange to the old-time foreman or production manager, who considers inspection to be a brake on the wheel of progress, but the emphasis is on the word "saleable." Without inspection, larger quantities may be produced, but they will be of inferior quality and will frequently require considerable hand work during erection. This finally reduces the output

[1] *Laws of Manufacturing Management*, p. 409.



(*Courtesy of Institution of Mechanical Engineers*)

FIG. XIII.3. THE CONTROL CHART AS A GUIDE TO ACTION

per worker, increases the cost of the goods, and makes interchangeable manufacture and proper servicing almost impossible.

The attainment of quality control depends on the degree of independence enjoyed by the inspection department. If this is subordinate in any way to the production department, quality will give way to quantity, whenever disputes arise. Questions of cost may prevent the use of an organized inspection department in some small plants and, in that case, the foreman, or one of his skilled assistants, is deputed to keep an eye on the quality of the work and to test the finished product, but whenever possible, the functions of inspection and production should be separate and of the same standing. The inspector should be of such calibre that he can not only determine what is wrong with an article, but can also discover the source of the trouble and suggest means for rectifying it. In this way the inspection function can serve a very useful purpose.

The objects of inspection are—

1. To detect and isolate faulty material or work and so to prevent waste.

2. To protect the purchaser against payment for faulty or defective goods.

3. To call attention to incipient defects before they become serious.

4. To ensure that operators are paid only for good work done.

5. To prevent further work being done on pieces that are already spoiled.

6. To promote interchangeability and to eliminate selective assembly.

7. To protect the reputation of the selling firm by reducing the number of complaints from customers.

8. To protect the customer against loss or damage.

9. To detect sources of weakness, trouble, or danger in the finished articles and so to check the work of the designers.

The organization of the inspection department[1] varies in different industries, but generally some or all of the following sections are present—

(*a*) Materials inspection.
(*b*) Machining or manufacturing inspection.
(*c*) Equipment and tool inspection.
(*d*) Erection or assembly inspection.
(*e*) Testing of components and complete machines.

[1]For characteristic details see "Quality Control in Manufacture," by Frank J. Feely, *Mechanical Engineering*, October, 1935, p. 638.

Inspection of Materials.

This may include all matters relating to the quality of material as received or as changed by manufacturing processes such as forging, casting, heat treatment, etc. The part played by thy inspectors in the receiving and identification of goods has alreade been indicated in Chapter X, but before the material is released for production purposes, the samples selected for testing must be examined in the laboratory. Physical, chemical and microscopic tests are usually made in the case of steel and other metallic materials, and these will be discussed briefly in turn.

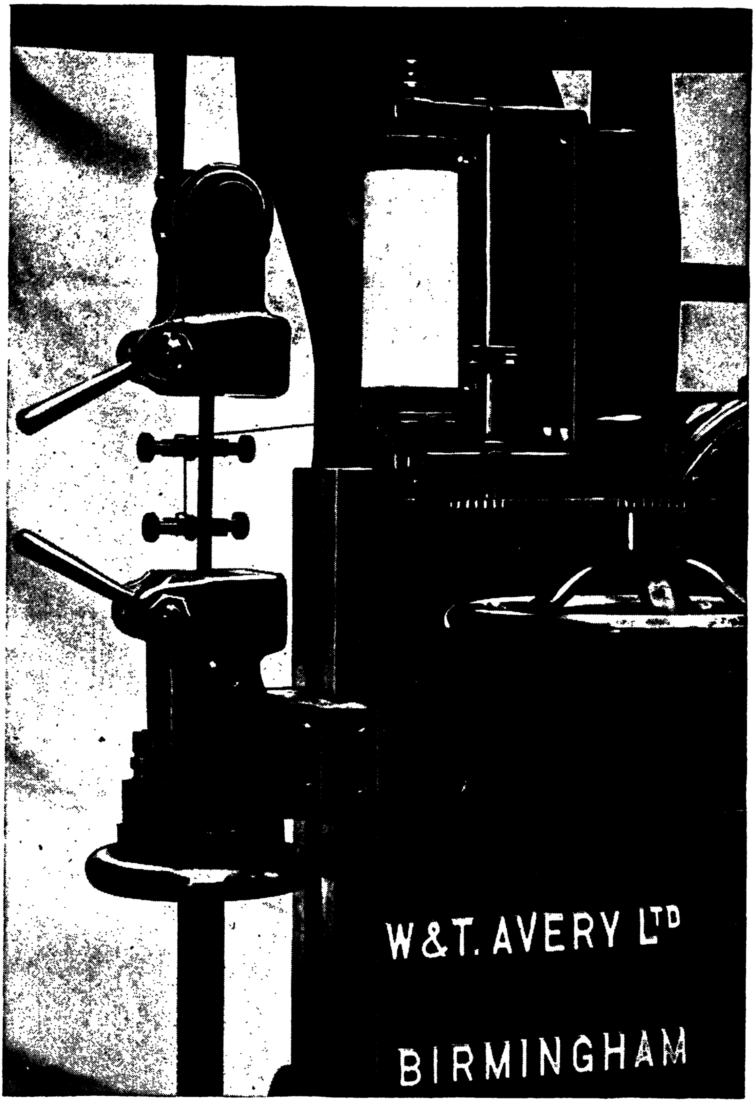
The physical tests employed vary with the nature and use of the final product, but they usually apply to the sample one or more of the following: pull, push, bend, cut, twist, strike, indent, or abrade.

They almost invariably include a tensile test, in which the yield point, breaking or ultimate strength, extension and reduction of area, are measured. The specimen or test piece must be of standard dimensions because the ratio of the measured length to the cross-sectional area is important.

Many large testing machines are operated by hydraulic power, and with these machines, it is important to have an accumulator or other device for keeping the pressure constant and its application free from jerks. Most of the smaller machines are operated by electric motors, which are preferably of the variable speed type,[1] so that the straining speed can be adjusted easily and conveniently. These machines can generally be equipped for making compression and bending tests by the addition of special tools for the purpose. The former are required for tubes, timber, and concrete, and the latter for beams, plate work or foundry test bars. Desirable properties are accuracy, sensitiveness, speed, reliability and convenience of operation, but some of these properties are mutually exclusive, so that a compromise must be made in favour of the machine embodying most of them.

An extensometer for automatically recording the load-extension curve (Fig. XIII.4.) is frequently useful, as the form of this curve gives a valuable indication of the physical properties of the material. Hardness is tested by means of a Brinell, Rockwell, or similar machine, which uses a hard ball or prism to produce an indentation in the surface of the material. These are

[1]For details of testing machines and apparatus see *Materials and Their Application to Engineering Design*, by Allcut & Miller (Griffin & Co.).



(*Courtesy of W. & T. Avery, Ltd.*)

FIG. XIII.4. EXTENSOMETER MOUNTED ON TENSILE TESTING MACHINE

seldom used on case-hardened or ground surfaces on account of the indentations which remain after the test has been made, and also because of surface cracks which radiate from them. Bouncing tests, such as those applied by the Shore Scleroscope, are more suitable for this purpose, but for these, a smooth, hard surface is required. Impact or drop tests are applied to measure the resistance of the material to shock, the Izod and Charpy machines being standard for small specimens. Special machines and tools are made for sheet material, fatigue, and other testing purposes.

Chemical analyses are made for the purpose of ascertaining whether the material is of the right composition, and if the various elements are within the limits prescribed by the specification. *Microscopic tests* check the *arrangement* of the various elements and give considerable information regarding the *condition* of the material. These are sometimes amplified by the use of sulphur prints or other methods of examining the flow of material, segregation of impurities, etc., in the forgings. Recently, considerable progress has been made in the application of X-rays for detecting hidden defects in materials or structures, and most of the engineering societies have published papers on this subject.[1]

The detection of foreign matter in foodstuffs and other materials, either before or after packaging, is also facilitated by this means. The apparatus used is shown in Fig. XIII.5. where the packages are examined as they pass under the screen so that every article is examined on the conveyor. One prominent candy manufacturer has made a special study of this factor, and Fig. XIII.6. indicates the appearance of foreign matter when examined in this way. Its importance to such firms is emphasized by the large number of lawsuits which have arisen during the last few years from damage claims made by customers who are alleged to have swallowed such foreign matter and claim to have suffered serious injuries.

Magnetic methods (Magnaflux) have also been devised and used to detect flaws or cracks in materials.[2]

[1]The use of radium for this purpose is described by V. E. Pulling, *Proc. I. Mech.E.*, March, 1933, p. 305. It may be employed in the investigation of metals up to 8 in. or more in thickness.

See also *Industrial Inspection Methods*, by L. C. Michelon, for details of inspection procedure and apparatus.

[2]See *Mechanical Engineering*, March, 1937, pp. 147–155; and Michelon (loc. cit.), Chapter XIX.

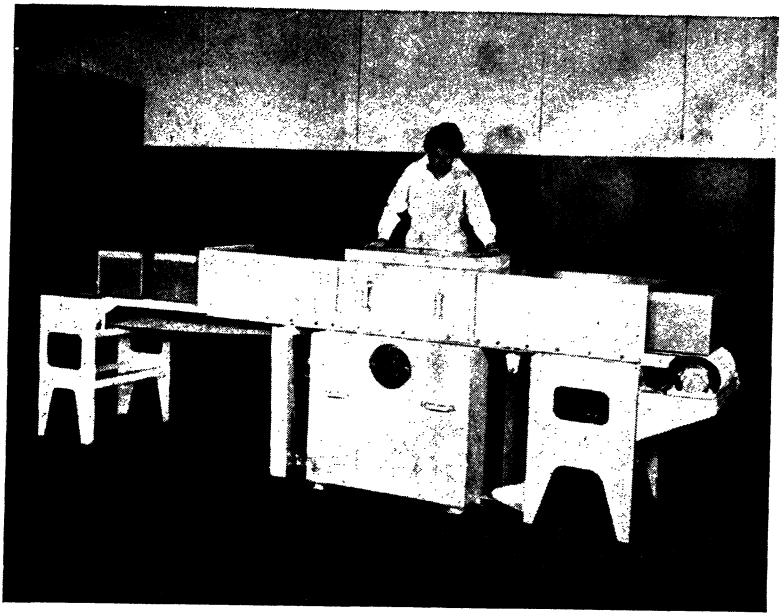


FIG. XIII.5. X-RAY APPARATUS FOR EXAMINING MATERIAL ON CONVEYOR

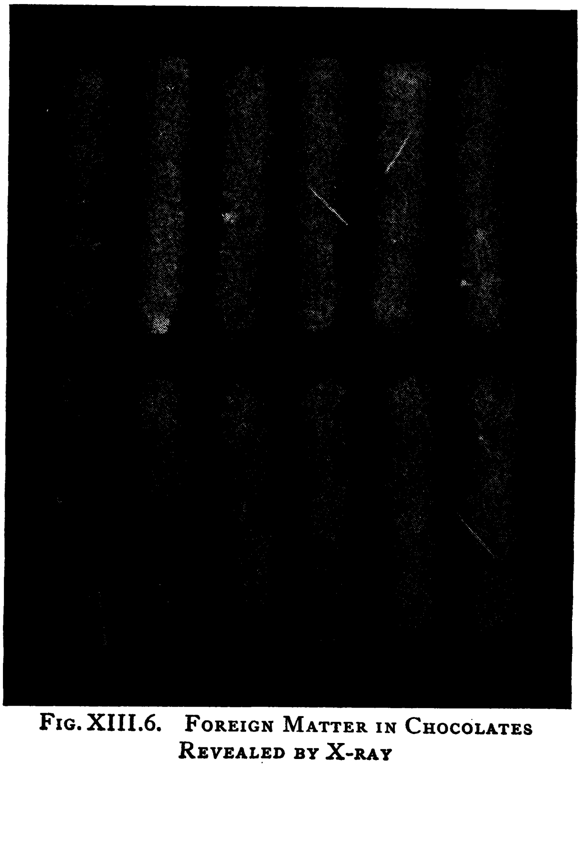


FIG. XIII.6. FOREIGN MATTER IN CHOCOLATES REVEALED BY X-RAY

Metallic materials arrive at the factory in the forms of bars, billets, sheets, castings, or forgings. A superficial examination of the rolled material reveals surface defects such as minute cracks or blisters, want of straightness or flatness, piping, or laps. Faint seams on the surface of a steel billet may appear to be unimportant, but if the steel is to be used for drop-forging purposes, such defects frequently open out under the hammer or in the hardening process. Suitable gauges must be available for dimensional examination. These should preferably be of the limit type. Ring gauges should be used for bright bar stock, as the bars are sometimes oval in section and will not enter the collets of an automatic machine. These are not the only troubles met with. They are mentioned by way of example.

The number of test pieces to be selected is usually given in the specification as a percentage of the number of bars in the consignment, and the procedure for machining and heat-treating them must be described in detail on the instruction sheets.[1]

When material is received in the form of castings or forgings, it is advisable to arrange for a sample to be sent for examination before manufacture is commenced. This sample is marked out to ascertain whether the articles made from the same moulds or dies will enter the jigs, also whether there is an excessive or insufficient amount of material for machining purposes. The sample is then usually cut into sections to expose eccentricity of cores, spongy material, and other hidden defects. The bulk supplies sometimes have test pieces cast or forged on them. This is a convenience, but is frequently misleading as the section of the test piece is often different from that of the rest of the metal. This causes differences in cooling or forging conditions, so that the structure of the test piece is different from that of the article to which it is attached. When circumstances permit, it is advisable to cut test pieces out of the castings or forgings themselves, but this is not always practicable. Scrap articles are sometimes used for this purpose. If the articles are covered with scale, it is advisable to remove this by pickling them in dilute acid before inspection as the scale frequently covers serious defects. Sand blasting is also used for this purpose but is not always as effective as the pickling process. The removal of scale and core sand also reduces wear of tools and facilitates the machining process.

Inspection after rough machining will frequently reveal

[1]See *Engineering Inspection*, by Allcut & King, p. 49.

spongy places and blow holes (Fig. XIII.7.) which are immediately below the surface. An examination at this stage frequently saves considerable money, particularly in the case of gear work. Many castings, such as cylinders, radiators, etc., must be tested for soundness by water pressure before being used. In some

FIG. XIII.7. DEFECTS IN BORE OF MONOBLOC CASTING
Magnified by Oblique light

instances, the use of hot water will reveal defects that were not apparent in the cold-water tests. Air pressure (as in the case of tires) is used for a similar purpose.

The proper maintenance of patterns, cores, and dies is an important matter in quantity production work, and may well be supervised by the inspection department.

Material that has been rejected may be repaired by welding or patching, and in this case it must be inspected with great care to see that the repair is a sound and workmanlike job (Fig.

XIII.8). There is also the possibility of distortion if welding is improperly done.

The principal troubles met with in forgings are seams, laps and overheating. Burnt metal can be detected by the appearance of the "flash" which is sheared off when a drop forging is finished. Forging in an improper direction, so that the lines of

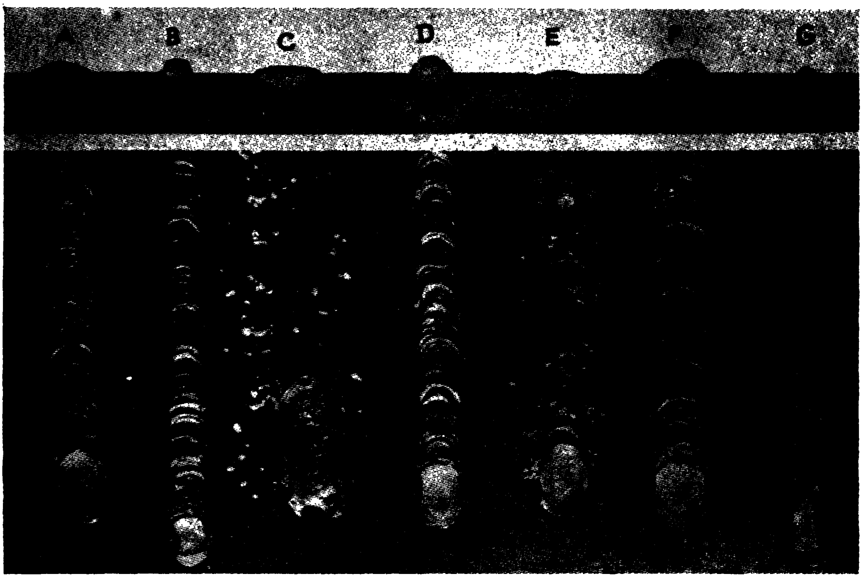


FIG. XIII.8. GOOD AND BAD WELDS

Plan and elevation of welds made with shielded arc electrode under various conditions: (a) current, voltage and speed normal, (b) current too low, (c) current too high, (d) voltage too low, (e) voltage too high, (f) speed too low, (g) speed too high.

flow are across instead of along the article, may lead to local weaknesses (Fig. XIII.9). The formation of gears is a case in point. Formerly these were forged on the "flat," so that the lines of flow were *along* some of the teeth and across others. This difficulty was remedied by cutting the billets into short lengths and forging them endways so that all of the teeth in the finished gear were equally strong.[1]

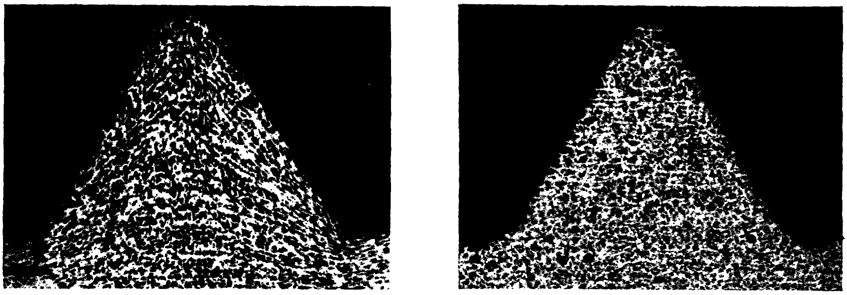
Tubes are tested for soundness and superficial defects, and, in the case of copper, are tested by bulging, flanging, or flattening to ensure that the material is of the desired quality.

Other tests for these or similar materials will readily suggest

[1]For details, see *Materials and their Application to Engineering Design*, by Allcut and Miller (C. Griffin & Co.).

themselves, but the above are representative of most engineering work.

Material arriving at the factory in the finished state may have been passed by the outside inspector before it was forwarded, in which case it should bear a tag or stamp to indicate this fact. If inspection is necessary on arrival, the parts may be dissembled and a percentage of them tested separately, as above.



Micro-photographs illustrating the grain flow in (a) a rolled thread, and (b) a machine-cut thread

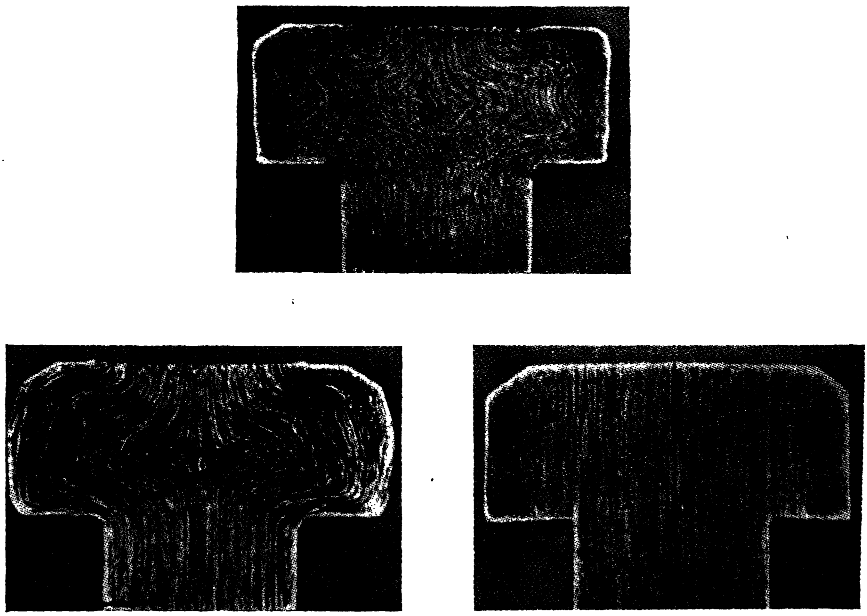


Photo-micrographs illustrating the grain flow in (a) a correctly cold-headed bolt, (b) an incorrectly cold-headed bolt, (c) a machined bolt

FIG. XIII.9. WEAKNESS INDICATED BY LINES OF FLOW

The method of selection in this and in other inspection operations depends on the importance of the part under review. With very important work, every article must be examined, but in others, a definite proportion,[1] which varies in individual cases, is chosen for examination frequently by using statistical methods.

With ordinary sampling or selective inspection, if all of the samples are satisfactory, the whole lot or consignment is passed, but if some are found to be defective, every one of that batch must be inspected. If possible, the articles passed for use should be stamped with the number or symbol of the inspector, so that responsibility may be definitely allocated. In some instances, material rejected after selective inspection must be sorted by the operator responsible for producing it.

Case-hardened work must be tested for superficial hardness and for condition of case and core. This involves a fracture of the test piece that was carburized and hardened with the articles. The test pieces should be of similar dimensions and form to the articles that they represent, otherwise the depth of case is likely to be different from that in the articles themselves. Also, the parts should be carburized in boxes, so shaped that there is an even thickness of carburizing material round them, otherwise some of the articles will be heavily cased and in others the case will be thin. Local softness, due to unsuitable cooling media or other conditions, must also be detected by the inspector. These examples show the variety of work that has to be done by the inspector of materials, and indicate the need of both care and experience on the part of that official.

Machining Processes.

The number and arrangement of inspectors or viewers required for this purpose depend on the quantity of similar articles that are being produced. If the work is of a non-repetitive character, a foreman or charge-hand may undertake its inspection. Again, a more or less fluid inspection system may be devised to follow up all the jobs in the shop, each man being responsible for certain orders or for a certain class of work.

In quantity production, the inspectors are usually placed "in line," each viewer examining the product after a particular process, and so becoming skilled on that job. Strategic points at which defects are likely to be apparent, are picked out for each

[1] "Inspection Methods in Industrial Plants," by Carl. L. Bausch, *Mechanical Engineering*, July, 1938, p. 555.

item, and the articles are checked at that point either completely or by selection. One detail may be inspected at several different stages, while others are examined only at the end of the machining operation. One man may check a single process or may inspect a number of different articles.

Standard gauges and inspection fixtures are provided, and are checked at intervals in the gauge room for the purpose of avoiding progressive errors in dimensions. A view room or other bond should be provided in each department, and in this, rejected articles should be kept until their fate has been decided. They should then be sent to a rectification section for adjustment, or should be scrapped forthwith. The inspector responsible should make up his mind quickly, as disputed articles waste considerable time and are a source of constant irritation. When definitely rejected, these should be defaced, otherwise they are likely to creep into production again *via* the scrap heap.

Inspected articles should be stamped in a definite place, so that each viewer will know where to look for the stamp of the previous inspection operation. This saves considerable time and is a safeguard against "short cuts." The inspection record should also indicate the number passed, rejected, and sent for rectification.

An important part of this section is the "sample view," which is an examination of material produced from a new machine or "set-up." This is a check on the setting and tools used. It prevents the operator from producing faulty work during the time that would normally elapse between starting a new job and inspection of the operation or product.

The smoothness or "finish" of the surface of machined or ground surfaces, which was formerly estimated by sight or touch is now susceptible to measurement. A rough guide is by comparison with standard samples which are obtainable with various degrees of finish but a more accurate determination may be made by means of a profilometer or profilograph. In these instruments the movement of a tracer point across the surface is magnified optically or electrically and may be recorded for future reference or for comparative purposes. Microphotographs of irregularities revealed by oblique light beams, interference bands set up on the surface by using a light source and an optical flat and the swing of a controlled pendulum are other means of measuring surface finishes.

Equipment and Tool Inspection.

The attainment and maintenance of the desired standard of quality and interchangeability depend upon the accuracy of the machine, tools, and measuring instruments used.[1] Machines become worn or get out of line, bushes become slack, and other imperfections become manifest after the factory has been in operation for some time. The inspectors can assist the production department very materially by pointing out these defects before they become serious, but this must be done tactfully to avoid friction. The accuracy of gauges and other measuring instruments, however, is purely an inspection matter. These should be checked at regular intervals, the frequency depending on the amount of use.

The procedure used by an English firm[2] for this purpose is described as follows—

> Effective control of gauges is an essential feature of inspection, and provision is made for gauges to be checked at predetermined intervals; this is done by means of a card index system. On receipt of a gauge from the tool inspection section a card is filled in with details of the gauge number, serial number, and the period which the gauge may be in production before it is withdrawn for check. For shop gauges this period is determined by the tolerance of the component for which the gauge is required, this method of fixing the period being found most suitable, owing to the difficulty of forecasting the amount of use the gauges may or may not have in the shops. For inspection gauges the period is determined by applications. In general, the period may vary from 1 to 6 weeks, and control is maintained in the following way—
>
> On receipt of a request for a gauge, the Gauge Control Bureau enters the particulars of the issue on the appropriate card to which a coloured metal signal is attached denoting the period which the gauge may be in use before it is withdrawn for check. The card is then filed and at the end of the week all colours are changed, until a final colour is reached, then all gauges corresponding with the cards which contain the final colour are withdrawn for checks.

An American automobile firm has[3] a permanent history card for each gauge, including frequency of inspection required. The gauges are inspected at the times indicated on the cards and re-

[1]The principles of dimensional control, methods of making fine measurements and the principles of gauging, are described in a paper by I. H. Fullmer in *Mechanical Engineering*, December, 1935, p. 772. This paper also contains a useful list of references. The Third Calvin Rice Memorial Lecture (A.S.M.E.) by H. Törnebohm, also dealt with "modern tolerance requirements and their scientific determination." It was published in *Mechanical Engineering*, July, 1936, p. 411. See also *Mechanical Engineering*, March, 1941, p. 223.

[2]Symposium of Papers on Quality Control, *Jrl. I. Mech. E.*, December 17, 1943.

[3]*Industrial Organization and Management*, by Bethel, Atwater, Smith and Stackman, Chapter XV.

pairs and corrections are made as required. With progressive wear the time of replacement can be estimated in advance. About 5000 gauges are inspected daily.

It is also claimed that deep-freezing at –100 to –120° F. assists in maintaining gauges and reference blocks at fixed forms and dimensions.

The measurement of dimensions introduces the following terms—

The *nominal size* of a dimension or part is the size by which it is referred to as a matter of convenience.

The *basic size* is the theoretical size from which variations are tolerated (the nominal and basic sizes are often the same).

The *limits* for a dimension or part are the two extreme permissible sizes for that dimension: they define the boundaries of the tolerance zone.

The *tolerance* on a dimension is the difference between the high and low limits of size for that dimension. It is the extent of variation in a dimension which may be permitted or "tolerated" to allow for unavoidable imperfections in workmanship.

Allowance is the prescribed difference between mating parts to attain a specific class of fit. It may be the minimum clearance or the maximum interference.

It should be clearly understood that tolerance and allowance are two separate and distinct things.

This implies some standard from which the variation can be measured. With a hole and shaft, both nominally 1 in. in diameter, there are four dimensions to be considered—

(*A*) The minimum diameter of the hole.
(*B*) The maximum diameter of the hole.
(*C*) The maximum diameter of the shaft.
(*D*) The minimum diameter of the shaft.

If all of the shafts are intended to enter all of the holes, it follows that (*A*) must always be greater than (*C*), but under these conditions a shaft made of minimum dimensions may be assembled with a hole of maximum dimensions so that the clearance may then be excessive. In such cases selective assembly may be used, but this is frequently an expensive process.

There are three types of fit, namely—

1. *Clearance fits* in which (*A*) is greater than (*C*), so that there is always a positive allowance. These are divided into running and push fits, depending on the amount of this allowance.

2. *Transition fits* where (*A*) is about equal to (*C*). These include key and light-drive fits.

3. *Interference fits* in which (A) is less than (C), so that varying amounts of force are necessary for assembly. These are divided into drive, force, and shrink fits. The last have so much overlap that the hole must be expanded by heat before the shaft can enter.

In the *uni-lateral* system of limit gauging,[1] the nominal size is the minimum diameter of the hole (A), and all tolerances of holes are measured above this diameter. In this case, the maximum shaft diameter (C) is (A) minus allowance, and minimum shaft diameter (D) is (C) minus shaft tolerance. Thus, for a 1 in. diameter hole let

$$(A) = 1.000 \text{ in.} \qquad (C) = 0.998 \text{ in.}$$
$$(B) = 1.002 \text{ in.} \qquad (D) = 0.995 \text{ in.}$$

The maximum clearance between shaft and hole is thus .007 in. and the minimum is .002 in.

The *bi-lateral* system has a nominal size which is the arithmetic mean between (A) and (C), or a nominal diameter of $\frac{A + C}{2}$.

Both uni-lateral and bi-lateral systems are in use, but the former is generally the more convenient of the two.

The accuracy of measurement necessary in modern production work is exemplified by the following table of limits for a high-grade automobile[2]—

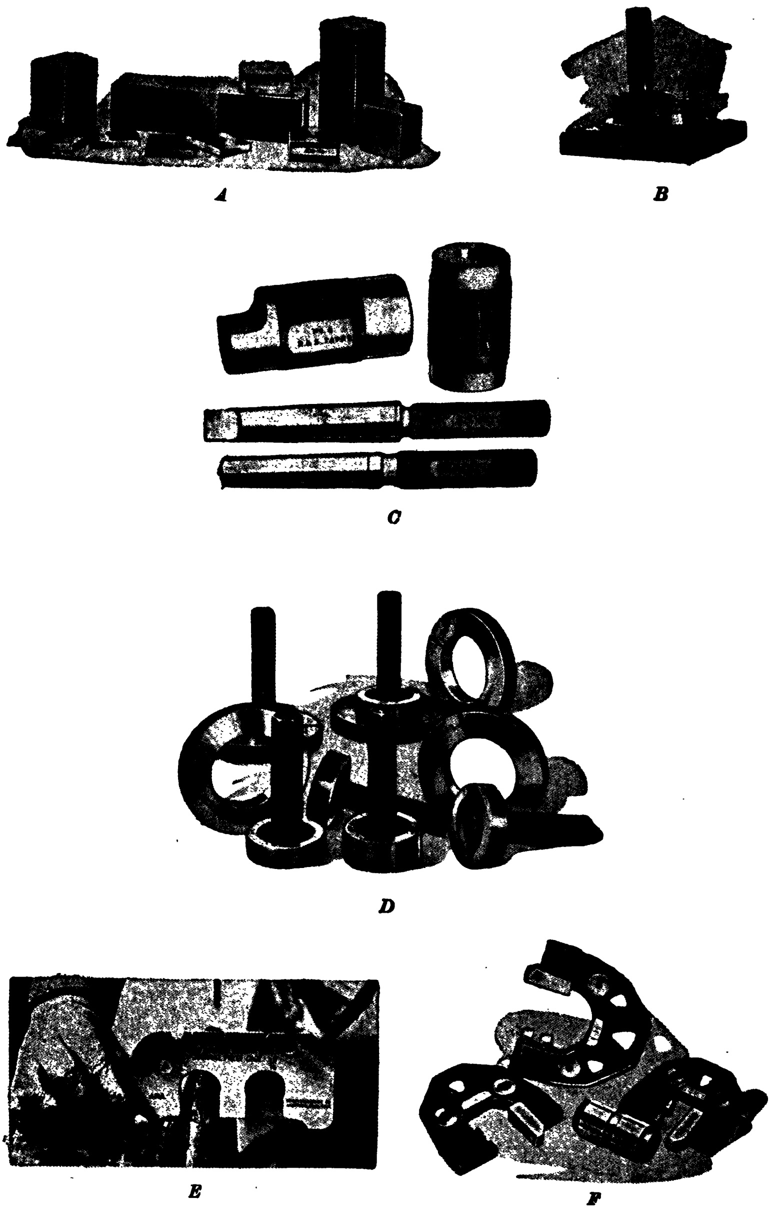
Limits	Number of Operations
.002″	36,000
.001″	22,000
.00025″ to .0005″	800

This means that, in the case of 800 of the dimensions on the car, the actual size must not vary more than one-fourth to one-half thousandth of an inch, and 36,000 of them must not vary more than two thousandths of an inch. The measuring instruments used must, therefore, be sufficiently accurate and sensitive to indicate these differences.

Gauges[3] or measuring instruments are of three types—

1. *Fixed gauges* (Fig. XIII.10.), whose size is not controlled by the operator. These are frequently of the "go" and "not go"

[1]An International System of Fits, proposed by the International Standards Association, is described by Gaillard in *Mechanical Engineering*, August, 1931.
[2]From *Manufacturing Industries*, Vol. II, No. 6.
[3]See *Engineering Inspection*, by Allcut & King, Chap. VII.



(*Courtesy of Pratt and Whitney Co.*)

Fig. XIII.10. Fixed Gauges

A and *B* = Standard measuring blocks.
C = Taper gauges.
D = Plug and ring gauges.
E = Plate gauge.
F = Snap gauges.

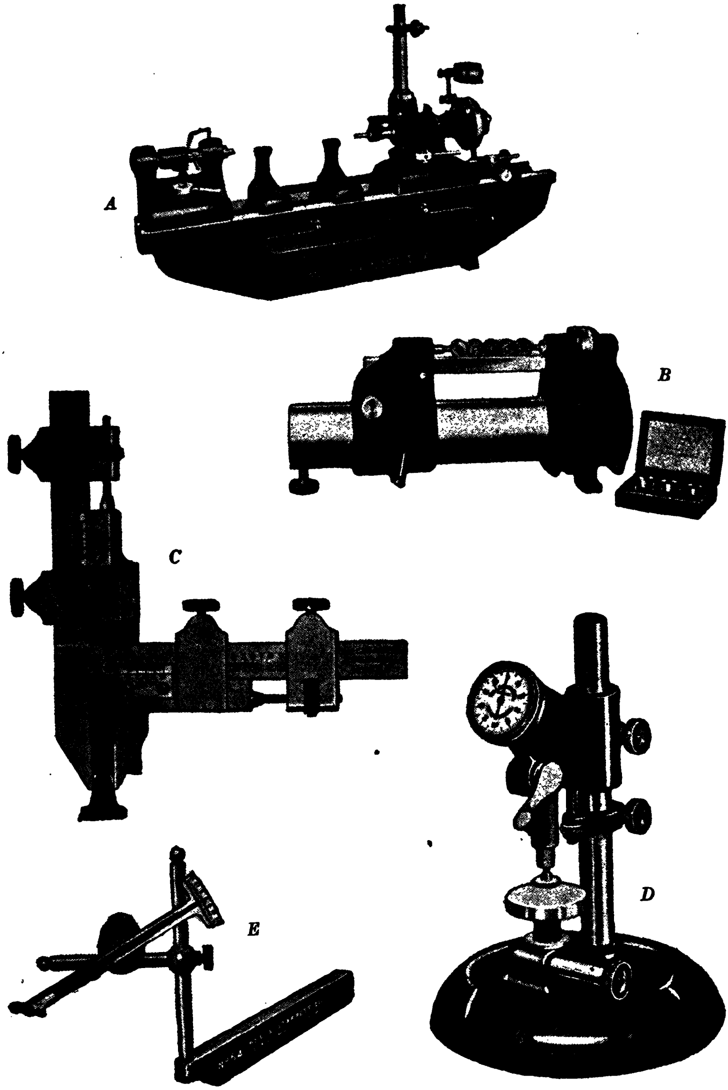


FIG. XIII.11. ADJUSTABLE AND SELF-RECORDING MEASURING INSTRUMENTS

A = Measuring machine. *B* = Super micrometer.

(*Pratt and Whitney Co.*)

C = Gear tooth vernier calipers. *E* = Universal test indicator.
D = Self-indicating dial gauge.

(*L. S. Starrett Co.*)

type, the former being the working side. They are simple in operation. They allow no discretion on the part of the viewer as he has no means of ascertaining by how much the work is outside the prescribed limits. The work either fits the gauge or it does not. Such gauges must be checked periodically for wear and kept free from damage or distortion. Some of them are purposely made of brittle material so that in the event of their receiving a blow, they will break rather than bend.

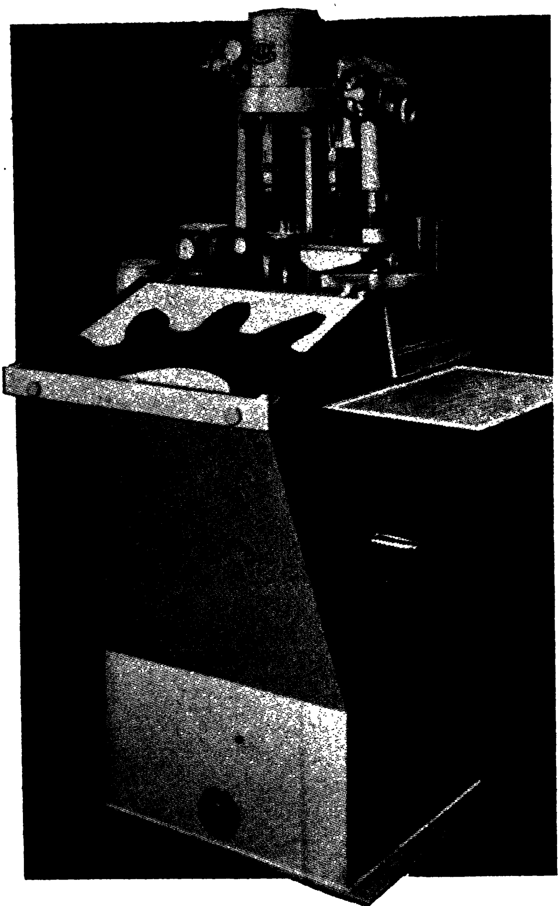
2. *Self-recording instruments* (Fig. XIII.11.), such as dial indicators, the readings of which are taken by the viewer. These are mostly used for detecting eccentricity, bending of shafts, surface irregularities, or distortion after heating. The range of indication is usually small, frequently being not more than $\frac{1}{10}$ in., and therefore these instruments are used for detecting variations from a standard, rather than for making definite measurements of sizes. They are made with multiplying levers, knife-edges, or racks and pinions, so that the movement of the plunger can be magnified to any desired extent. In some instances, optical lever systems are substituted for mechanisms.[1]

Projectors, for magnifying screw threads or gear teeth, are different in detail but serve a similar purpose in that they do not always measure sizes but detect variations from standard. One form is shown in Fig. XIII.12, where an enlarged image of the gear teeth is thrown on a translucent screen between maximum and minimum outlines, which are drawn upon it. Errors in the form of thread, lead or pitch are easily detected by this apparatus.

Electrical indicating gauges are of three types: (*a*) those depending upon a change in inductance which unbalances a bridge circuit; (*b*) those in which the gauge contact point actuates a segmented commutator, the segments of which are connected through lights, relays, or other signalling devices; and (*c*) those depending on capacity changes of condenser plates used as indicators, i.e. ultra-micrometers.

The first type will accurately produce magnifications from 500 to 100,000 times the movement of the gauging contact point. A 500-cycle alternator supplies electrical energy to a small transformer which in turn supplies energy to four inductances, two of which are small coils in the electric gauge head. The inductance of these is varied by the movement of a pivoted steel lever arma-

[1]See "The Application of Optics to Engineering Measurements," *Engineering*, 6th August, 1937.



(*Courtesy of* Swiss Technics)

FIG. XIII.12. UNIVERSAL PROFILE PROJECTOR

ture, one end of which moves between the coils as the contact point on the other end conforms to the surface of the piece being measured. The other two inductances of the bridge together with the transformer and indicating instrument are mounted on a unit which is placed in easy view of the operator.

One of the most recent developments in ultramicrometers is that by Reisch which gives a straight-line relation between indicator reading and the distance moved by the condenser plate, and eliminates errors of mechanical and temperature disturbances of the moving plate. This design uses two fixed plates with a movable one midway between for the measuring head,

and a vacuum-tube bridge as indicator of the differential change in capacity. Maximum sensitivity of the order of 1 or 2 $\times 10^{-7}$ in. can be attained.[1]

Another form of indicator is the air gauge or comparator which is used mostly for checking internal cylindrical surfaces. One form operates on compressed air, the pressure of which is regulated automatically. The greater the clearance between the gauging head and the cylinder to be measured, the greater will be the quantity of air leaking through that clearance. This increases the velocity of the air passing through the indicator tube and causes a float to rise in the tube. The position of the float therefore indicates the difference in diameter between the measuring head and the cylinder.

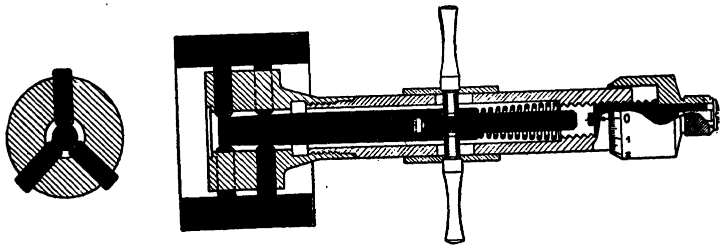
Combination and automatic gauges are now employed to check a number of different dimensions simultaneously and to flash warning signals or to stop the machine when the desired dimensions are being approached and reached respectively. With these special purpose gauges rapid inspection of large quantities can be obtained.

3. *Adjustable instruments* (Fig. XIII.11.), in which the skill of the user is an important factor. These include calipers, micrometers, verniers, etc., special sizes and forms being made for specific purposes. For instance, micrometers for measuring fabric or other compressible material, must have large anvils, while those for thread measurements must have one anvil of the pointed form. Those for plates or sheets must have deep frames, and others are made adjustable for measuring different thicknesses. Three-point micrometers (Fig. XIII.13.) are used for large cylindrical holes, while special verniers are made for a number of different purposes.

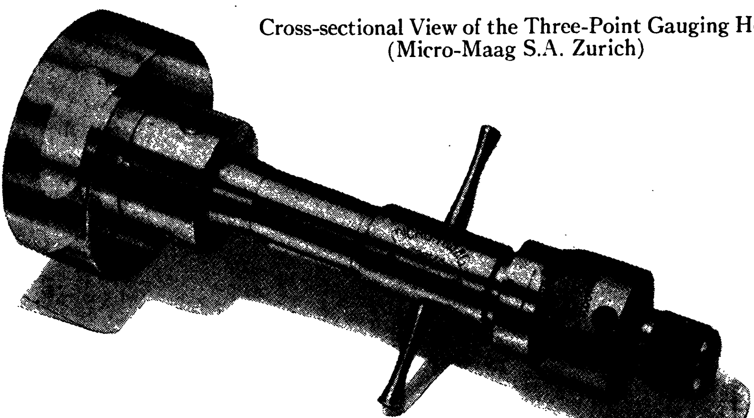
4. *Master and Reference Gauges.* Where work is being produced to limits, it is advisable that the gauges used by the operators shall be within the limits of those used by the line or shop inspector. Thus, if wear occurs in the former, the work produced will still pass the gauges of the latter. The viewers' gauges in turn must be within the limits of the reference or master gauges, which must be kept in the gauge room, and under no circumstances be allowed to enter the shop. These master gauges are used only for checking purposes, and they themselves are calibrated by means of measuring machines or gauges of the

[1]From *Mechanical Engineering*, December, 1935, p. 779.
See also "A Convenient Electrical Micrometer," R. Gunn, *Journal of Applied Mechanics*, June, 1940, and Michelon (op. cit.), Chap. X.

"Johannsen" or similar type (Fig. XIII.10.). The gauge room, where the standards are housed, should be kept at a constant mean temperature (68° F. or 20° C.), as delicate measurements are affected by changes of temperature.



Cross-sectional View of the Three-Point Gauging Head
(Micro-Maag S.A. Zurich)



(*Courtesy of* Swiss Technics)

Internal Measuring Micrometer
(Micro-Maag S.A. Zurich)

FIG. XIII.13. THREE-POINT MICROMETER

A scheme for identifying and controlling the use of limit gauges by colour is described in *Engineering*[1] and is claimed to have been used successfully with native labour in the Soudan on the inspection of locomotive valve gears.

Fitting and Assembling.

The principal objective of machine shop inspection and of the use of precision tools, is to eliminate expensive hand work, so that the articles leaving the component stores will assemble into the finished product without further adjustment. This is frequently impracticable, however, and some measure of inspec-

[1] "The Murray Colour Control System," *Engineering*, 8th February, 1935, p. 141.

tion must be provided at the assembly bench. Distortion, due to the gradual relieving of stresses in a machined part or to irregular tightening of nuts and bolts, is a frequent source of trouble.

The work of the erection shop inspector is more complicated than that of his colleague in the machine shop because the articles to be viewed are more complex, and the dimensions to be checked are composite rather than simple. The object of the viewer is to ensure that all details are fitted together without undue friction or play, and to see that the clearances prescribed are actually present. Bearings must be in line, surfaces flat, and all components correctly in place. Thus, the inspector of these operations must have a considerable amount of practical knowledge and preferably some experience in the running test, so that he can perform his duties with common sense and discretion.

The final erection inspectors have to see that the machine is sent out in good running order, that all necessary accessories and connections are in place, that all bolts and studs are fitted with nuts and locked where necessary, that oil pipes are in position, and that everything is ready for the final test. As the details to be observed are often numerous, a list of questions or a schedule of observations to be made is frequently supplied. The inspector ticks off each of these in turn so that nothing is omitted by mistake.

No alterations should be made after the inspection is completed, but, in some cases, pressure is brought to bear on the inspection department to pass material that is slightly outside the limits of accuracy prescribed. This is very undesirable, but sometimes the need for the articles is so great that special concessions are necessary. In such cases, the material passed in this way should be specially marked so that the inspectors will recognize it on arrival at the erection stage, and will watch it carefully during the assembly and running test. A record of the circumstances should be kept for future reference.

Final Tests.

The kinds of test applied to the finished work will vary in different industries, but usually they may be divided into three classes—

1. Running or Proof Tests. These tests are designed to ensure that all parts function properly, and that the necessary degree of strength, or safety, is present. In the case of engines,

the direction of rotation, lubrication, heating, valve and ignition timing are noted, and if the machine is defective in any of these respects, it may be rectified on the spot or returned to the erecting shop for adjustment.

Boilers are subjected to hydraulic tests to indicate weaknesses or leakages; ropes, chains and aeroplane wings have proof tests to show that their strength is greater than the prescribed minimum (Fig. XIII.14.).

Strain gauges are now extensively used in such tests to indicate deformations at important points so that any local weaknesses are revealed. Electrical apparatus is given insulation tests for a similar reason.

2. Consumption and Performance Tests. These are designed to indicate the power or economy of the machine, or its general efficiency of performance. They are much more expensive and complicated than running or proof tests, and therefore are not made on all products. In the case of an engine, the consumption of fuel, oil, and water, the power generated, the temperatures and pressures of the various fluids used, and the speeds at different loads are required, together with such other information as is necessary to see that existing standards are being maintained, or to observe the effects of improvements or changes in design. The methods of measurement used for this purpose are given in the appropriate books[1] and technical papers. They will not be described here.

Test codes have been published by the American Society for Testing Materials, the American Society of Mechanical Engineers and other technical organizations to standardize methods of testing in America; also by the Institution of Civil Engineers for Great Britain. The object of these codes is to show how measurements should be made, what kind of instruments should be used, and what methods of calculation or comparison should be employed for specific purposes. By this means, experimental errors may be reduced to a minimum and valid comparisons of performance may be made.

3. Acceptance Tests. These are made to satisfy a customer that his requirements have been met, or to cover guarantees of performance or efficiency. They may include any of the performance or consumption tests mentioned above and some others. For instance, the purchaser of an automobile is not usually interested in the indicated horse-power, but does want

[1]For example, *Experimental Engineering*, by Diedrichs and Andrae.

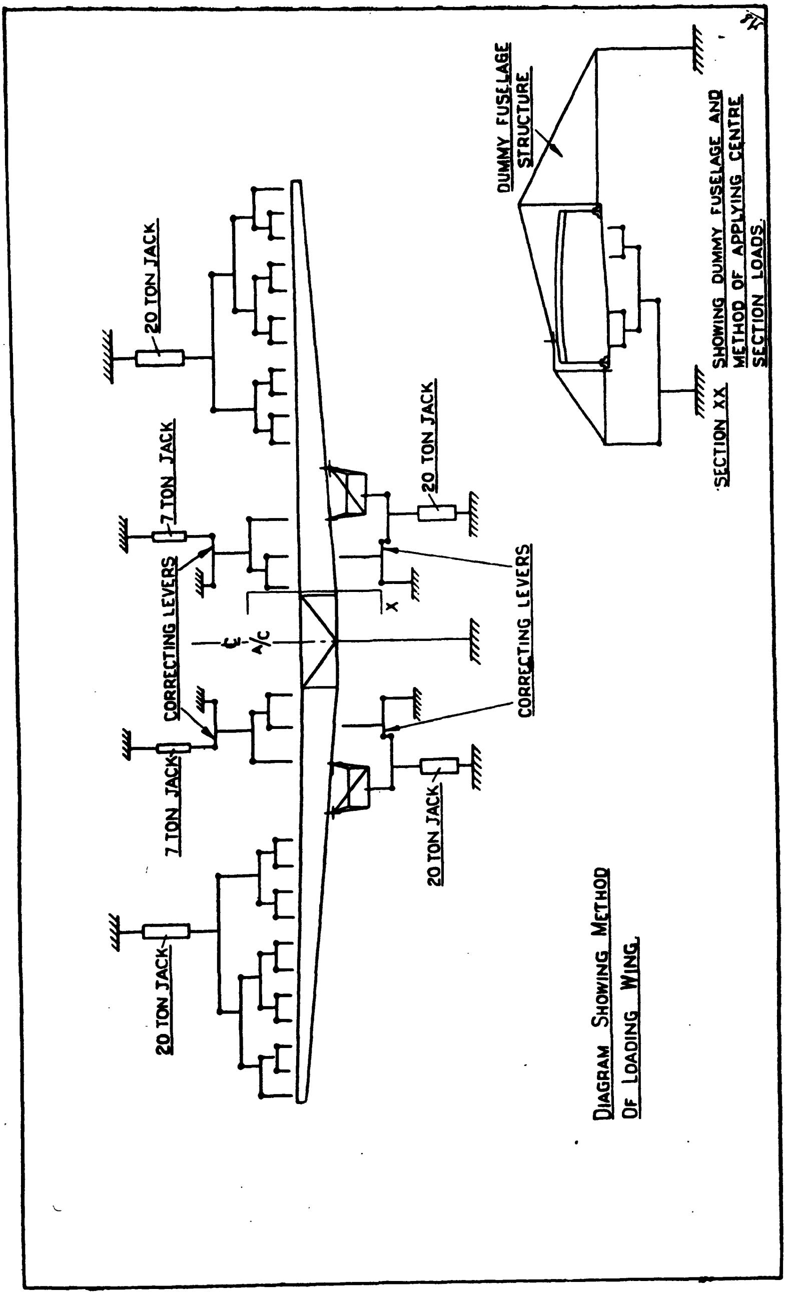


FIG. XIII.14. LOADING TEST FOR AEROPLANE WING

to know whether it will start and stop quickly, and whether it will climb a hill. A farmer does not care about the technical details of a tractor, but he is interested in the size of furrow that it will plough.

In some cases the machine is stripped and examined after the preliminary tests are made, so that any faulty parts may be replaced before the final test is performed.

Machines and structures that work in unusual temperatures and pressures must be tested in appropriate surroundings. An example of this is the testing of aircraft and aircraft parts.

Airplanes must work equally well in the arctic and in the tropics, which regions are now less than a day's flight apart. In the stratosphere the temperature is $-67°$ F. At that temperature most lubricants get stiff, windows have a tendency to frost over which defeats their very purpose, rubber is not very rubbery, neither is the binder in shatter-proof glass. The major aircraft companies in an effort to avoid cold trouble at high altitudes are now installing cold rooms in which a good size refrigeration plant maintains a temperature of $-70°$ F. The cold laboratory at the Douglas Aircraft Co., Inc., has a capacity of 60,000 BTU per hr. The room is 14 by 11 by 8 ft. in size; and heavily insulated. Access is afforded by a double door entrance lock. A small blower is available to simulate a cold air blast. In this room mechanical, electrical, and hydraulic accessories such as control hinge and lever mechanisms, pumps, valves, and materials for windshields, windows, diaphragms, seals, and caulking can be tested for functioning, tightness, or brittleness in extreme cold.

Some rather unexpected things happen to materials, structures and, not to forget, to the human organism at high altitudes because of the low atmospheric pressure prevailing up there. Air bag pillows and sponge rubber having closed cells grow to almost twice their size when brought to 20,000 ft. Double-glazed hermetically sealed window sash will bulge; warm gasoline evaporates and causes vapour lock; pumps are harder to prime. At extreme altitudes ignition sparks will jump across insulation gaps.

Repairs, Rectifications, and Obsolete Parts.

In mass production work, special operations, which do not come within the prescribed scheme, must be performed in a section of the shop set aside for the purpose. This work is of a varied character, and requires a large and miscellaneous collection of gauges and drawings, some of which are several years old. Familiarity with the types of machine formerly made by the factory is sometimes necessary, as the older drawings may not contain the limits that are now considered to be essential for accurate replacement work.

Rectification of current work comes within a different category. This concerns material which cannot be taken through the usual production processes, but may be reclaimed and made usable by careful manipulation, so that the articles may be returned to the production line at the earliest possible stage. Such pieces must be specially marked so that they will not be taken away and put through the ordinary production routine until the rectification processes have been completed. Examples of this are heat-treated parts that have been heated to remove broken drills or taps, and must be returned to the hardening shop for re-heat treatment before the machining is resumed. Scale and distortion may make some of them useless, and the cost of reclamation must be considered before this procedure is attempted. Filling blow holes, welding cracks or other defects, come within a similar category, and in some cases, mistakes in machining may be rectified if the number of parts is sufficiently great to make the process economical.

Inspectors and Viewers.

It has been clearly demonstrated on many occasions that an inspection system, properly organized and operated, assists production, but a good deal depends on the personality of the men who carry out this duty. Co-operation is essential if good results are to be obtained, and the work of the inspector must be of a constructive nature. It is not sufficient for him to reject faulty work, but he must be able to trace troubles to their respective sources and so assist both the designers and the purchasing department.

Many of the inspectors are not qualified by education or experience to do this; they are merely gauge operators or "viewers," and should be given no discretionary power. All articles rejected by them should be reviewed by a superior class of inspector who has power to pass this material if he considers it to be usable. Viewers must be steady, reliable, honest, and must have a considerable amount of tact to avoid friction with the operators whose work they have to inspect. Written instructions should be issued for each job, but when there are many of these, the viewer must be able to remember most of them so that they can be applied promptly when required.

Inspectors, generally, must be diplomatic but firm in their decisions without being obstinate. If fresh evidence, which has a bearing on previous decisions, is brought forward, they must be

sufficiently open-minded to review the case on its merits and to weigh the value of the new evidence in its relation to the facts previously known.

Systematic organization is necessary to avoid overlapping and excessive costs, but sometimes reduction of inspection personnel should be avoided because the moral effect of the presence of an inspector on the job is frequently an insurance against spoilage and loss. The inspector must have the ability to separate essentials from non-essentials and the courage to act accordingly, as no firm can long survive a policy of indiscriminate scrapping.

The efficiency of an inspector is defined by Juran[1] as—

$$\text{Efficiency} = \frac{D - K}{D - K + C}$$

where D is the number of defects reported by the inspector
K is the usable material actually present in D
C is the number of defects not reported by the inspector, but discovered by independent examination of the articles passed by him.

The difference between this figure and 100 is due to the following types of error—

(*a*) Errors in reading measuring instruments.
(*b*) Errors in judgment.
(*c*) Errors in recording.

In some cases there is a tendency to favour certain readings or certain limits or to "crowd observations round the scale graduations." These tendencies may be involuntary or deliberate, and in some instances, it is advisable to use an experienced man to check the work of the inspector.

The efficiency of inspection is sometimes affected by physiological conditions. The examination of white enamelled surfaces in the production of stoves, refrigerator bodies and other similar articles takes place in a "tunnel of light," giving an intensity of 185 foot candles at the point of inspection. This caused a considerable amount of eye strain, so that assembled jobs were rejected because the colours failed to match satisfactorily. The inspectors were then fed 30,000 units of Vitamin "A" per day, and this increased the colour sensitivity and decreased eye fatigue. The consequence was that the rejects fell from an average of 1.7 per cent to 0.2 per cent.

[1] "Inspectors' Errors in Quality Control," by J. M. Juran, *Mechanical Engineering*, October, 1935, p. 643.

CHAPTER XIV

THE PAYMENT OF LABOUR

Wages.

One of the most difficult problems in industrial work is that of determining wage rates. With the advent of competition, the easiest way of reducing costs was to cut wages, and the payment of labour became a question of supply and demand. This is indicated by Alford's law of relative wages[1]—

Wages tend to lower when the supply of labour exceeds the demand: wages tend to rise when the supply of labour is insufficient to meet the demand.

This law, however, does not meet the difficulty of fixing a standard or base rate upon which the variation of pay may be superimposed. In some countries or localities, the cost of living is so low that a worker and his family can live in comfort on a sum of money that would be totally inadequate elsewhere. The term "counterfeit wages" has been used by Filene[2] to indicate the reduction of the purchasing power of money due to high living costs, and he comments on it as follows—

"Counterfeit wages have too little value, when measured against the purpose which wages must serve. It is not a question of how much a man receives, but of what he can buy for what he gets. Wages may double, but if prices are more than doubled, the wages are counterfeit to the extent that prices have outrun the increased wages."

A high "counterfeit" or "nominal" wage may amount to a low "actual" or "real" wage where—

(*a*) The cost of living is high.

(*b*) The worker's active industrial life is short due to unhealthy working conditions or continuous over-exertion.

(*c*) The work is of a very localized or specialized nature.

(*d*) Working periods of intense activity alternate with periods of idleness (e.g. some seasonal trades).

Various theories[3] have been advanced in connection with wage payments, including—

1. The "subsistence" theory that wages tend to fall to a level

[1] *Trans. A.S.M.E.*, December, 1926, p. 410.

[2] *Industrial Management*, December, 1922, "Why Men Strike."

[3] A detailed survey of the economic principles involved in the payment of wages is given in *Compensating Industrial Effort*, by Z. C. Dickinson (Ronald Press).

that just enables the worker to live and to support a family. The argument is that a higher rate tends to produce an increase of population, which intensifies labour competition and tends to reduce wages; also that a lower rate tends to reduce the labour supply by malnutrition and starvation.

2. The "wages fund" theory, that wages are derived from an accumulated store of capital during the inevitable delay that exists between the time when the work is done and the time when payment is received.

3. The "productivity" theory which is that most generally accepted at the present time. This is indicated by Alford's law of Wage Level, as follows—

The normal wage level of each country depends upon and corresponds to that country's general average productivity of labour.

Thus, to the supply and demand and cost of living factors is added a third, namely, the average production of the individual. Rates of wages, therefore, should depend upon the worker's contribution to industry, as only in this way can the industry remain solvent.

This consideration, however, involves the different viewpoints of employer and employee. The former wishes to buy labour as *cheaply* as possible so as to reduce his costs and increase his profits; the latter to sell his labour as *dearly* as possible. The employer wants a large output per man; the employee is not interested in output unless his pay is increased accordingly. Although increased output usually benefits the worker, directly or indirectly, he is likely to look upon it with distrust because he considers that it increases unemployment. The reward offered, therefore, must be sufficient to overcome this reluctance. Several schemes, which will be described later in this chapter, have been devised for this purpose.

The operation of the laws of transfer of skill and ownership (Chapter I) left the worker at the mercy of the factory owner, and this together with the aggregation of firms, caused a similar organization into labour unions on the part of the workers. The result was that the basic rates for the remuneration of labour were based rather on bargaining power than on justice, and the *minimum wage* became an important factor in industrial disputes.

"The main objects of minimum wage legislation are the prevention of unduly low wages, or what is generally called "sweating," the suppression of the unfair advantages enjoyed by some business firms in the payment of lower wages than those gen-

erally recognized and paid in the industry, and in some cases, the promotion of industrial peace. The Select Committee on Home Work (England) stated that sweating obtains when work is paid for at a rate which, in the conditions under which many of the workers do it, yields to them an income which is insufficient to enable an adult person to obtain anything like proper food, clothing, and house accommodation."[1]

This still leaves in the air the vexed questions of the maintenance of a family, variations in standards of living, and saving for unemployment, sickness, or old age. It follows, therefore, that these basic rates are generally fixed by collective bargaining or by legislation, and that the operation of most wage plans is relative to these standards.

The cost of living varies not only from place to place, but also from time to time. This is taken care of by *sliding scales,* which affect either the scale of payment or the variation of a special bonus that is added to the basic rate. Both of these methods are in operation, the main difficulties being those of finding a "cost-of-living index" that bears any relation to the actual cost of living.[2]

Some firms have adopted a deliberate policy of paying higher wages than those customary in the surrounding district. They have been successful by reason of increasing efficiency of organization and operation, and by increasing the output per worker, thus reducing overhead costs. It is now generally understood that high wages do not necessarily produce high labour costs. It does not pay to have a cheap and inefficient man operating an expensive machine. In all types of work, freedom from labour troubles and increased co-operation produce decided economies.

The Commonwealth Court of Conciliation and Arbitration was established in Australia in 1904 to prevent and settle industrial disputes and, as wage rates are the principal causes of such disputes, this matter has received considerable attention. The first minimum wage established in 1907 was 42 shillings a week for unskilled workers. This was called the "basic" wage and was determined originally to meet the needs of an unskilled worker with a wife and three children. Margins above this were provided for skill and for other special reasons. The basic wage was increased by about 7 per cent in 1921, and a special reduc-

[1] *The Evolution of Industrial Organization,* Shields, pp. 171–2.
[2] See *Compensating Industrial Effort,* by Dickinson, p. 264.

tion of 10 per cent occurred in 1931. Wages are adjusted to the cost of living every three or six months, on the basis of a food and rent index number computed by the Commonwealth Statistician for the locality in which the persons affected were employed.[1]

Job Evaluation.

The determination of the relative values of work done by different classes of people is a difficult matter as there is no recognized means by which these values can be assessed. In some instances rates of payment are decided rather by political than by economic factors and the injustice of this lies in the fact that if one section of the community receives more than its fair share of the national income, the others have to take less than their fair share. An attempt has been made during the past few years to put the wage structures in particular industries on a reasonable and equitable basis by means of Job Evaluation. The following summary of the procedure to be adopted was taken from a report of the Association of Professional Engineers of the Province of Ontario.[2] The forms given in the charts are not complete and the "point values" are illustrative only and are not representative of any particular plan.

Step I. Obtain a complete description of the duties, responsibilities, etc., of each of a few "key" jobs in the organization, for which the rate structure is to be set up. Pick these "key" jobs to cover the entire range from the lowest to the highest skilled job to be included in the structure. (It is desirable to choose as "key" jobs those of which the duties and qualifications are fairly well known and most commonly recognized.)

Arrange the descriptions so they can be easily analyzed into such fundamental elements as job knowledge required, experience, ability to analyze problems, initiative to carry job through to completion, responsibility for costs, leadership, etc. Below are shown parts of a typical form for recording job descriptions.

Step II. Carefully compare the jobs, element by element, at the same time assigning relative numerical values to each, according to the amount of job knowledge, responsibility, etc., re-

[1] "Industrial Relations in Australia," *Mechanical Engineering*, February, 1939, p. 148.

See also "A Floor under Wages—British Style," *Mechanical Engineering*, September, 1939, p. 676.

[2] "Principles of Job Evaluation in the Determination of Equitable Salary Structures" (December, 1942). See also *Job Evaluation and Employee Rating*, by Smyth and Murphy, (McGraw-Hill), 1946, and *Job Evaluation*, by Johnson, Boise and Pratt, (John Wiley), 1946.

CHART I

PARTS OF A TYPICAL FORM FOR JOB DESCRIPTION

JOB KNOWLEDGE

Indicate Minimum Education Desirable:
High School: 1 – 2 – 3 – 4 – 5 years.
Business or Technical School: 1 – 2 – 3 – 4 years.
University: 1 – 2 – 3 – 4 – 5 – 6 – 7 years.
Other courses..........

Experience and Training:
Years of previous experience usually required for average person to qualify for this job..........
List classes of work, types of equipment, materials, etc., on which the employee is required to be informed to carry on his work. Underline those items on which the employee is required to be especially well informed and on which he is called upon to advise management or others

RESPONSIBILITY FOR COSTS AND SERVICE

What type of cost, expense, or waste is job responsible for?..........
What type of service is job responsible for? (Production schedules, customer service, etc.)..........

PERSONAL REQUIREMENTS

Types of persons contacted (associates, management, public, etc.)..........
Type of presentation (selling, purchasing, routine, etc.)..........
Subject matter of contact (advising on design, obtaining bids, etc.)..........

ANALYSIS AND INITIATIVE

List briefly the types of problems that must be analyzed and on which some action should be taken or some creative ability employed..........

quired by the job. Total the numerical values of elements for each job to get a total rating for the job. This step should preferably be done by a committee of at least three men qualified to judge the job.

Chart II shows a typical breakdown of job requirements into elements, with definitions of the elements and the maximum point-values allowed for each element.

Step III. Plot on a graph these total-point-values against the existing rates being paid in the community for these "key" jobs. Draw a curve through the weighted average of these rates to obtain what is known as the "community average line" (illustrated in Fig. XIV.1.) This curve will indicate when rates for some jobs are "out of line" in relation to their point evaluation.

Step IV. Set up an organization rate structure to be used as a guide in making salary adjustments, pointing out promotional sequence, planning training programmes, etc. (See Fig. XIV.2). The adopted average line is drawn with the community average line as a guide. Maximum and minimum lines are drawn to

CHART II

TOTAL POINTS 2500

Knowledge with the ability to apply it on the job.	**SKILL 1350 POINTS**	JOB KNOWLEDGE (450 points) The formal schooling experience and training required to do the job. (Consider years of schooling plus the years or months of experience and training necessary to develop a satisfactory worker.) ANALYSIS AND INITIATIVE (600 points) The ability required to analyze and understand problems arising on the job. To take effective or creative action on these problems without undue direction from supervision. PERSONAL REQUIREMENT (300 points) The tact, agreeableness and ability to get along with others in the presentation of facts and regular job contacts.
Accountability for results, probable chance of errors and their cost in the regular performance of the job.	**RESPONSIBILITY 650 POINTS**	LEADERSHIP (325 points) Responsibility for selection, organization, supervision and development of personnel to carry on departmental duties as efficiently and economically as possible. COST AND SERVICE (260 points) Responsibility required for the handling of items that might affect costs (money, materials, equipment, waste). The responsibility for and degree of service to associates, other departments, customers and the public required by the job. ACCURACY AND DEPENDABILITY (65 points) Degree of accuracy and dependability required by the job; importance and probable cost of errors.
	APPLICATION 100 POINTS	Degree and continuity of mental and physical application required by the job. Fatigue or "wear and tear" resulting from the job.
For all employees.	**BASE POINTS 400**	Basic allowance represents minimum requirements an individual must have to secure employment with the organization.

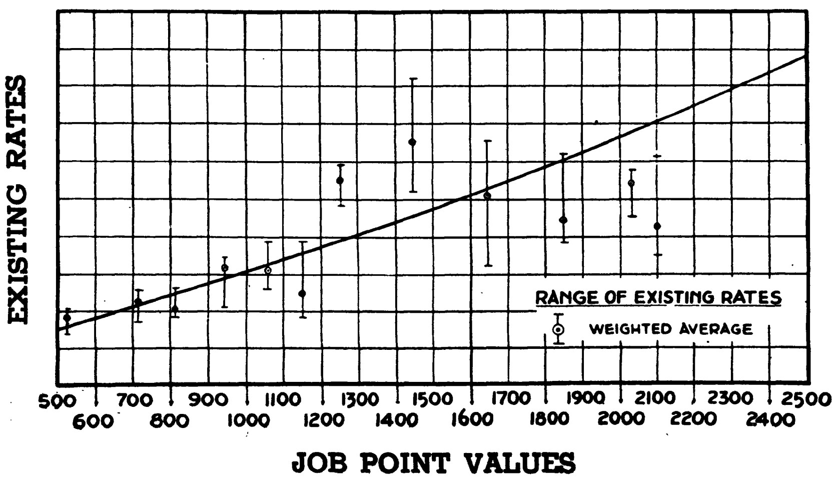


Fig. XIV.1. Community Average Line (Hypothetical)

allow a salary range on each job for "beginners," "average," and "maximum-performance" employees.

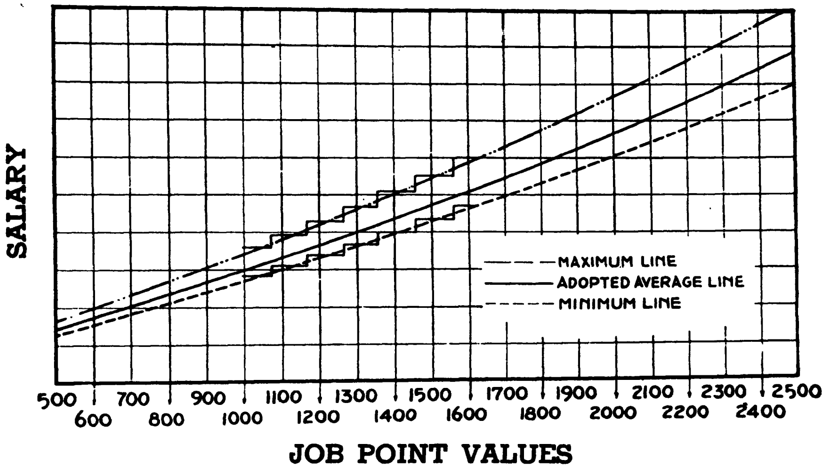


FIG. XIV.2. RATE STRUCTURE

Step V. Obtain descriptions and point evaluations of all other jobs to be included in the rate structure and compare them with the "key" jobs, fitting them into their proper place on the rate-structure curve. If the "key" jobs have been carefully studied and properly rated, the proper rating of the remaining jobs will be comparatively easy.

Relation to Cost of Living. The entire rate structure can be raised or lowered in accordance with changes in cost of living in any community without disturbing the relation between jobs within the rate structure.

Merit Rating. Job evaluation is the placing of a value on a certain job regardless of the person who is holding the job. Some persons, however, may be able to fill that job better than others; and, therefore, job evaluation should be supplemented by a "merit rating" plan which indicates whether the individual should receive the minimum, average, or maximum rate allotted to the job according to his performance. Chart III shows a typical form for use in merit rating.

Consider how well individual fills requirements of job. Where possible, consider employees relatively for each element. Check in degree for each element. Avoid extremes for all but

the exceptional cases. Refer to the job description blanks for job requirements.

CHART III

	DEGREE OF EACH ELEMENT POSSESSED									POINT EVALUATION	
JOB SKILL—Knowledge with the ability to apply it.	High			Average			Low			Job	Man
1. Job Knowledge Consider the extent to which employee fills the educational, experience and training requirements of the job.											
2. Ability to Finish Jobs (analysis and initiative) Consider individual's ability to analyze and grasp essentials of job problems and to take effective or creative action without undue supervision.											
3. Personal Requirement Consider tact, agreeableness, co-operativeness, and skill in presentation and ability to get along with fellow workers and superiors as required by the job.											
TOTAL JOB SKILL %											
JOB RESPONSIBILITY—Accountability for results, probable chance of errors, and their cost in the regular performance of the job. **4. Leadership** Consider the leadership displayed in organizing the effort of others, and in supervising, inspiring, selecting, and developing others.											
5. Responsibility for Cost and Service Consider how well individual assumes responsibility for costs, wastes, and service as required by job.											
6. Accuracy and Dependability Consider accuracy, thoroughness and reliability shown on job.											
TOTAL JOB RESPONSIBILITY %											
7. Application Consider degree and effectiveness of applied effort.											
TOTAL PERFORMANCE RATING %											

To insure fairness and an unbiassed appraisal, employees should be merit-rated by three qualified individuals who pool their judgments and reconcile differences of opinion.

Administration of the Plan. To be successful, a plan of wage and salary classification must be systematic, fair, and uniform. It must also provide for adjustment to changes in job content and in personnel performance. These requirements are best met by continuous and centralized supervision, actively supported

by management, and working co-operatively with supervisors and employees.

CHART III (Cont'd)

(Supplementary information for the use of management)

Capacity for Growth ....Should advance steadily. ....Shows promise of future growth.	State what next job in line would be.............................. ....
..............................Could handle more work on present job.	What should be added to job?..............................
..............................Limited to present job.	
..............................Unsatisfactory for present job. ....Merits further consideration.	What type of job is he fitted for?.............................. ....
..............................Does not merit further consideration.	State reason..............................
REMARKS: (State whether employee is trying to advance himself by study. List courses, etc. Use reverse side of this sheet if necessary)..............................	

Advantages of Job Evaluation. The advantages to employer and employee of a job evaluation scheme are as follows:

(1) It gives reasonably complete, accurate and impersonal description of jobs useful for:

(a) Periodic review of duties to determine if some duties have become obsolete and should be discontinued or revised. (Example: The keeping of reports or records whose usefulness has not proven to be in keeping with the cost of maintaining them.)

(b) Guiding employers in assigning employees to positions for which their qualifications are best suited.

(c) Guiding employers in selection of new employees to fill vacancies.

(d) Guiding employers in setting up a proper sequence of promotions.

(2) It suggests the need for and the character of improved methods growing out of job analysis and the review of the job at each merit rating.

(3) Where merit rating is used, it obliges the supervisor to study his jobs and his men, resulting in possible improved economy of work and recognition of merit in individual employees.

(4) It draws attention to problem cases.

(5) It stimulates self-improvement in employees by pointing the direction in which they can concentrate their efforts.

(6) It gives management a check on its supervisors and shows how well they have allocated the work to employees.

(7) In general, it improves employer-employee relations.

(8) It tends to establish a healthier industrial condition in any community.

(9) It assists an employee to obtain adequate recognition for his services.

(10) It gives employees assurance of equal pay for equal services rendered.

Payment by Time.

This is sometimes called the "day rate" system though usually the time of the worker is actually purchased by the hour, except in the case of the higher executives who receive salaries which are based on monthly or annual amounts. Although the medieval craftsmen were frequently paid by the job or "piece," payment by time is probably the oldest method under the present industrial system.

After the Industrial Revolution, and in some cases before it, men hired themselves out to the owners of machinery in much the same way as agricultural labourers did to the farmers. This method was fairly satisfactory in the primitive state of industrialization. The owner or foreman was able to keep in personal touch with each operator, to distribute rewards or punishments with full knowledge of the facts in each case. Even then, payment was really based on piecework, as there was a tacit understanding between employer and employee that a certain minimum amount of work should be produced per day, but with improvements in machines and other facilities for doing work, the amount that it became possible to do was not definitely known.

There was also a very definite understanding between the men that no more than a certain amount of work should be produced, and any man infringing this understanding by producing more than that amount was immediately in trouble with his shop-mates. This limitation of output (otherwise "soldier-

ing" or "ca' canny") was widely practised in engineering shops. Taylor says that "under this plan, the better men gradually but surely slow down their gait to that of the poorest and least efficient. When a naturally energetic man works for a few days beside a lazy one, the logic of the situation is unanswerable. 'Why should I work hard when that lazy fellow gets the same pay that I do and does only half as much work?' " He found that this tendency could only be overcome by offering inducements in the form of higher pay.[1]

> The writer has found, for example, after making many mistakes above and below the proper mark, that to get the maximum output for ordinary shop work requiring neither special brains, very close application, skill, nor extra hard work, such, for instance, as the more ordinary kinds of routine machine shop work, it is necessary to pay about 30 per cent more than the average. For ordinary day labour requiring little brains or special skill, but calling for strength, severe bodily exertion and fatigue, it is necessary to pay from 50 per cent to 60 per cent above the average. For work requiring especial skill or brains, coupled with close application, but without severe bodily exertion, such as the more difficult and delicate machinist's work, from 70 per cent to 80 per cent beyond the average. And for work requiring skill, brains, close application, strength, and severe bodily exertion, such, for instance, as that involved in running a well-run steam hammer doing miscellaneous work, from 80 per cent to 100 per cent beyond the average.

The principle of payment by time is generally unsatisfactory (save when it is based on Job Evaluation) because the pay received bears no relation to the amount of work done, and because it depends on the honesty of the man or the driving power of the management or both.

It has some advantages, however, and is still used in many shops, particularly in small factories where personal supervision is easy. The trade unions favour it because it facilitates mass bargaining, and because the findings of industrial commissions and arbitrators are easy to understand and apply. It simplifies the work of the pay department because the time cards indicate the amount of pay due, the rate being constant. The workman knows how much he will receive for his labour. He has a sense of security. Since he does not have to rush his work its quality will not suffer. For this latter reason, inspectors and tool-room operators are usually (though not invariably) paid by time. Time payment is also employed in cases where the work is difficult or of an unusual character, and during learning periods.

[1] *Shop Management*, by F. W. Taylor, Par. 33.

The objections are that it gives no incentive for a man to do his best, and although the work of the pay department is simplified, that of the cost department is made more difficult, as under this system wages are a variable element in the cost of a job.

Payment by time is still largely prevalent in many industries in spite of the numerous incentive plans that have appeared from time to time. In 1935 the National Industrial Conference Board of the United States found that in a number of typical manufacturing plants 56.3 per cent of the workers were paid by time, 22.1 per cent by piece work and 21.6 per cent by other incentive systems.[1]

Hours of Work.

The relationship of output to the number of hours of work has received considerable attention in recent years. Before the First World War, men in machine shops frequently worked for 53 hours per week, while now it is usually 44 to 40.

The humanitarian aspect of this is given in the following law—

"*All other factors influencing production being constant, a decrease in the hours of work increases the leisure of the workers, and an increase in the hours of work increases the comfort of the workers.*"[2]

If pressure for higher wages is good and "feather-bedding" is bad, pressure for shorter hours comes halfway. Since the national income is the product of the number of workers multiplied by what each worker produces in a year, any general reduction in the amount of work done must result in a national income lower than it would otherwise have been. In the particular circumstances of Great Britain today, a rapid increase in the total output of the whole community is most necessary to enable the nation to carry the burden it has assumed. But once the emergency has passed, the community will have a free choice between more wealth and more leisure. The economist can properly insist that it is a choice, and that the workers should not be deluded into thinking that they can have both at once. But if, understanding the choice, they choose more leisure and shorter hours rather than a higher standard of material consumption, the decision should be final. Leisure, after all, is a boon and a sign of wealth. A productivity policy should take as its criterion the output per man-hour and should leave to the democratic process the decision whether the wealth brought into existence by rising productivity shall be consumed in material goods or in leisure. In this general sense—and provided that the implications are understood—pressure for shorter hours does not run counter to the objects of a productivity policy.[3]

[1]See also "Wage Incentives," *Mechanical Engineering*, December, 1937.
[2]*Laws of Manufacturing Management*, by Alford.
[3]*The Engineer*, October 6, 1944, p. 263.

A reduction in the hours of work sometimes increases the output by reason of the fact that fatigue is reduced but, in the absence of suitable production incentives, this is not always true. Many industries, since the end of World War II, have experienced a reduction of output equal to or exceeding the reduction of working hours. In some cases, however, the shortening of the working week has been justified by results.

In 1946 an interesting experiment in the reduction in length of the working week was made by Lever Brothers Limited in Canada, whereby the hours of work for factory employees were reduced from 48 to 40 per week with no reduction in weekly earnings, and at the same time, with no increase in overall wage cost to the Company for a given volume of output. This was achieved as a result of the deliberations of a Joint Union-Management Committee, which investigated the efficiency of the labour utilization in each department of the factory, and eventually succeeded in reducing the overall wage cost for a fixed volume of output by more than 20 per cent, whilst still operating on a standard 48-hour week.

This reduction in overall wage cost was sufficient to justify a reduction in the working hours from 48 to 40 per week, and the payment of a fixed 20 per cent bonus to all hourly-rated factory employees who were thus able to maintain their total weekly earnings.

The pattern is an interesting one, in that it satisfies the workers' not unreasonable demands for a greater amount of leisure time without sacrifice of earnings, whilst at the same time avoiding product cost increases with their inflationary tendency. The extent to which such a scheme is applicable to other industries is, of course, open to question but there can be little doubt that potential savings in wage costs are available in most industries, and the method of joint investigation, whereby full co-operation of the employees themselves is obtained, is of undoubted interest.

The following conclusions were arrived at, after a wartime investigation made by the British Government on "Hours of Work and Absenteeism."

1. The results of this inquiry show that the time lost by factory workers through sickness, injury and absence without permission, when undisturbed by extraneous factors, varied with the weekly hours of work. It was usually low when the hours of

work were less than 60 per week, but increased as the hours increased up to 75.

2. The findings suggest that, over an extended period, the weekly hours of work should generally not exceed 60 to 65 for men and 55 to 60 for women.

3. In all the groups the workers were stimulated to an increased output after the collapse of France, and although it was physiologically impossible to maintain the maximum level reached, output in nearly every case has since remained above the previous level.

4. The beneficial effects of a reduction in excessive hours of work, together with the inauguration of staggered holidays, were reflected in an increase in the rate of working afterwards.

5. Labour wastage varied considerably from one factory to another. Some of the conditions leading to a high rate were the employment of women unaccustomed to factory work, or married women whose domestic responsibilities prevented satisfactory adjustment to factory life; difficulties of shopping and getting suitable meals, and the problem of transport, were important in this connection.

6. Women, on the whole, lost more time than men, for reasons such as those given in the previous section.

7. In conclusion, when it is remembered that many workers lived far from the factories, and had to face air-raids when travelling to and from work; that some had lost their homes and had to sleep in improvised shelters; and that often they had to wait outside in the cold and rain because of inadequate transport arrangements, the time-keeping of the factory personnel studied deserves high praise.

Piecework.

The principle of this system is the most logical of all methods of payment, as the worker is paid according to the amount of saleable work produced. The difficulties experienced with it have been due to the methods of application. In the first place, there is the difficulty, already mentioned, of fixing the value of the work done. Where there is no time study, the price to be paid for each article is set with reference to the prevailing day rate and previous records of performance, so that, with normal working, the worker receives the same pay as he did under time payment. If he works harder and produces a greater quantity of goods, his pay rises in proportion to the extra amount done.

That is, the worker receives the *full value* of the extra work done while the employer benefits by a reduction in the overhead charges per article produced. The profit obtained on each piece is thus increased, or alternatively, the selling price can be reduced and a greater sale obtained. The system is just and workable. It provides the necessary stimulus towards maximum production.

The principal troubles that arose were due to an inaccurate knowledge of the time required to do the work and to the greediness of both employers and employed. After the rates had been set, it was found that some workers were getting considerably more money than had been anticipated. This caused friction in the shops, due to inequalities in pay among men engaged on similar classes of work. In some cases, both machines and men were "worked to death" in the endeavour to set a high pace and gain the consequent reward.

The consequence was that some of the rates were "cut" to obtain uniformity of pay and to increase profits. In some instances this was done again and again. As a result, the men were finally working much harder than before and were getting no more money than under time payment.

Other difficulties resulted from the fact that the "good" and "bad" jobs, from a piecework standpoint, were not properly distributed, one man getting a succession of easy jobs and high rates, while another always had the difficult and low-paying jobs to do. Conditions due to poor maintenance and non-uniform material, which were not under the control of the worker, reduced his earnings, and further troubles arose when the day rates rose or fell. The adoption of piecework was also opposed by the trade unions because it did not provide for a minimum wage, but recently this system of payment has been recognized by them.

It is probable that the principal reason for this recognition is due to the increasing use of time study, which has enabled prices to be set with much greater accuracy than was previously possible. A further contributory factor is the realization of employers that rate cutting is a sorry and uneconomical business. Changes of rate are obviously necessary where improvements are made in production methods, but these can be dealt with by agreement. It is advisable that the following clauses be inserted in any piecework scheme—

1. All prices should be given in writing and should never be

reduced, unless increased facilities are provided, or unless the nature of the work is altered.

2. As a protection against mistakes, prices mutually arranged may, on application of either party, be brought forward at any time for consideration.

This implies the existence of some committee or other machinery for dealing with rate adjustments. When the basic rates change, it may be necessary for all of the piecework prices to be altered. This is a lengthy process. It is facilitated if these prices are expressed in terms of time instead of money. So long as the manufacturing processes are unaltered, the times will not be affected by such changes. As mentioned in the paragraph on payment by time, learners should be paid by the day until they have become familiar with the work.

With the piecework method of payment, it is easy to ascertain the labour cost of any job, but the overhead charges are variable, depending on the time taken to do the work. For tasks of a co-operative nature, gang piecework is sometimes used, including all workers whose collective efforts contribute to the final result. A variety of this is the *contract* system, by which the employer furnishes material and tools and the contractor supplies the men, who may be paid either by piecework or day work. As the contractor receives a lump sum for the job, this is a straight piecework transaction as far as he and his employer are concerned. This system was formerly very prevalent in foundries, ironworks, and assembly work, but now is infrequently used.

The Priestman system is another variety of collective piecework, which usually applies to the whole factory. A study is made of the output for a given period, before the system is introduced, and this becomes the standard output. If, during a similar period after the system has been in use, the output is 10 per cent higher than the standard, the wages of every one employed by the company are increased by 10 per cent.

The results of substituting piecework for day work vary under different conditions, but a Joint Investigating Committee (England)[1] stated that from a production standpoint payment by results was infinitely superior to payment by time. The report gives instances of reductions in the time of various shipbuilding operations after the substitution was made, varying from 51 to 74 per cent.

[1] "Engineering," October 26, 1922.

Premium Systems.

The word "premium" is rather loosely employed to indicate incentives of various kinds for increasing production. In this paragraph it refers to those systems of payment that are based on previous experience rather than on time studies, and which amount to a bonus for increased output based on existing time rates. All of them include a minimum wage by giving the usual time payment if the standard time is exceeded. The workman does not receive the whole of the saving made when he does work in less than the standard time, but this is divided between the employer and himself. There is no reason why premium systems should not be based on time studies, but in that event the standard fixed would be much more lenient than that in the task and bonus systems described below. The standard is, therefore, easier to achieve, but the incentive toward maximum production is also less because the bonus per article produced becomes less as the production increases.

These methods of payment offer less inducement for the employer to cut rates, as his profit increases with the amount propuced. He gains, not only by the reduced overhead costs but also by reason of his share of the increased output. One difficulty is that where the work is of a varied nature and the bonus or premium is calculated on each job, there is a distinct possibility of the man working fast on the easy jobs to get the advantage of the premium, and slowly on the more difficult ones to make use of the day rate. Needless to say, this is not satisfactory from the firm's standpoint. One disadvantage with all of these systems is the difficulty of calculating a man's pay and of predetermining costs.

(*a*) HALSEY SYSTEM. In this case, the man is not paid for the whole of the time he saves, but a certain definite percentage of this. The bonus or premium varies in different applications from 25 to 50 per cent. Thus, if the standard time is 10 hours, the time actually taken 8 hours and the rate of pay 60 cents per hour, the normal earnings for 8 hours will be \$4.80. But the time saved is 2 hours, and if the premium is 33 per cent, the bonus will amount to $2 \times 60 \times .33$ or 40 cents. Thus, the total pay is \$4.80 + 0.40 or \$5.20, and the actual rate of pay is 65 cents per hour.[1]

(*b*) ROWAN SYSTEM. In the Rowan System, wages are in-

[1]The rates given in the examples are comparative only and are not intended to be representative.

creased by the percentage which the time *saved* is of the standard time. Thus, in the example given above, the time saved is $10 - 8$, or 2 hours.

The Rowan premium is therefore $4.80 $\times \frac{2}{10}$ or 96 cents. The total pay for the job is $4.80 + 96 or $5.76, and the hourly rate is 72 cents. It will be noted that the hourly rate in this example is greater than that in the Halsey system, and this is true for moderate reductions below the standard time. For great reductions of time, however, the Halsey scheme gives the greater hourly rate, as will be seen from the curves (Fig. XIV.3). The rate of pay in the Rowan system can never be double the time rate, as the time would have to be reduced to zero for this to occur. (See Curves, Fig. XIV.3., and Formula, end of Chapter XIV.)

(*c*) BARTH SYSTEM. This is a modification of the Halsey plan in which the geometric mean is used, so that the hourly rate is doubled when the time taken is one-fourth of the standard time. The total pay is the square root of the product of the standard and actual times multiplied by the time rate. The above example gives a total pay of $(\sqrt{10 \times 8}) \times 60$ or $5.36, or 67 cents per hour. The curve rises rapidly near the standard time, and this makes it possible to dispense with the minimum wage or day work rate.

Task and Bonus Systems.

The main difference between the "premium" and "task and bonus" systems of payment lies in the nature of the task and the methods of determining the standard time. In the former case, this time is only occasionally determined by the time and motion study, and so premium systems are generally modifications of time payment. Task and bonus systems are based on times that are carefully determined after all possible facilities have been provided, and after the workman has been fully instructed as to the best ways of doing the job. The standard time, in this case, may be a little more than half that allowed in premium systems, but the operator is enabled to achieve it by means of the assistance provided by the management.

The importance of an objective of this kind and the incentive that it provides under unusual circumstances, are well illustrated by the following excerpt from the *Canadian Engineer*—

Industrial executives have, of recent years, shown increasing confidence in the method of stimulating output by assigning definite tasks

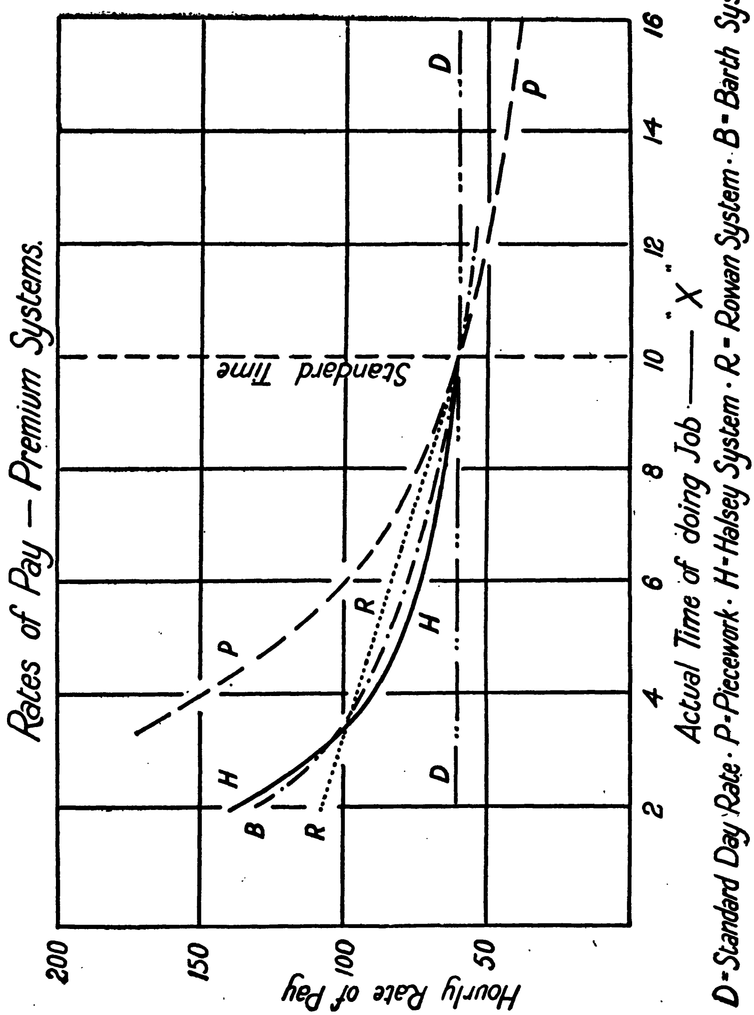

Rates of Pay — Premium Systems.
Standard Time
Actual Time of doing Job —— "X"
Hourly Rate of Pay
200
150
100
50
2
4
6
8
10
12
14
16
D
P
H
R
B
D=Standard Day Rate · P=Piecework · H=Halsey System · R=Rowan System · B=Barth System.

FIG. XIV.3.

to operatives. It appears to be the case that where a task within the power of the worker to accomplish is set, and some reward is given for the accomplishment of this task, either in extra compensation, or in reduced hours, the effect is unqualifiedly good. If, however, through error in setting a task that is too easy, the basis of compensation is revised so as to be less attractive to the worker, the whole system becomes discredited, and the work of the manager becomes more difficult than ever.

It has often been asked whether some form of the task system could not be adopted in construction operations. While little progress appears to have been made in this direction, there does seem to be an opportunity for a wide-awake construction manager to increase output by introducing the idea in some form in this field.

As an illustration of what can be done in excavation, a Canadian officer, who served long and with great distinction in the late war (World War I), reports an instance of a startling increase in performance by utilizing the task method. In the construction of trenches at night, he at first employed a working party of 100 men, working in pairs for five hours. At the end of that time, only about 400 ft. of trench was poorly done to a depth of 4 ft. Furthermore, there was much discontent, even from the best men. On the second night he set tasks of 6 ft. per man, marking them off by stakes. After two hours' work about 20 per cent had finished their tasks and were sent back to camp. After three hours 70 per cent had finished, and while a few had to be kept the full five hours, the 100 men had in that period completed 600 ft. of trench in a workmanlike manner. Thereafter the method of task-setting was employed by this officer with the utmost satisfaction.

There is, in this instance, food for a great deal of thought. If in one department of work high output can be encouraged by some preferential treatment of the efficient worker, surely something of the same character can be attained in other departments of work. It is a subject upon which construction managers might well ponder.

Another advantage derived from the setting of a definite task on standardized jobs is that it is selective in its operation, so that the best and speediest workers are picked out automatically. This does not necessarily mean that the speediest men always produce work of the best quality, but if the work done is of the prescribed standard, the man who produces most of it is of the greatest value to the firm. Most of the methods in use are varieties of the piecework system, and the remarks under that heading, with reference to difficulties in clerical work and costing, apply to task and bonus systems in greater measure.

(*a*) Taylor Differential Piecework. This consists of two piecework rates, the higher being paid to men who achieve the task in standard time or less, and the lower to those who fail.

Thus, the slow worker is penalized both by the smaller amount of work done per hour and by the lower rate at which he is paid.

Consider the example given in a previous paragraph where the standard time (for a greater quantity of work) is 10 hours and the basic rate is 60 cents per hour. If the work is done in less than 10 hours, assume that the bonus is 40 per cent and that the penalty for failing to achieve this standard is 25 per cent.

A man who does the job in 8 hours receives $\frac{1.4 \times 10 \times 60}{8}$ or \$1.04 per hour.

A slower worker takes 12 hours, and his rate is $\frac{.75 \times 10 \times 60}{12}$ or 37.5 cents per hour.

The severity of this penalty was deliberate, as Taylor wished to attract only the best workers and to eliminate the others, and this has caused the differential rate to be abandoned in most places. The incentive toward attaining the task, however, is correspondingly high.

(*b*) Gantt Bonus System. The Gantt task and bonus plan is a modification of Taylor's differential piece rate. Workers failing to achieve the standard time are paid the usual time rate, but a strong urge is put upon them to perform the task by giving a piecework rate of 20 to 50 per cent above the normal. This is usually lower than the higher rate offered by Taylor, as the possible saving is reduced by the workers who do not receive the bonus, but it is sufficiently attractive to induce them to do their best.

In the previous example, suppose the bonus is 25 per cent and the work is done in 8 hours.

$$\text{The hourly rate will then be } \frac{1.25 \times 10 \times 60}{8} = 93.7 \text{ cents.}$$

Foremen were allowed to participate in the scheme by paying them a bonus, the amount of which increased with the number of men who earned the premium by performing their allotted tasks in standard time. In all probability, this procedure also helped to remove slow and inefficient operators.

(*c*) Emerson Efficiency System. This differs from the Taylor and Gantt systems by giving no sudden increase of pay when the standard time is reached. The efficiency of an operator is expressed as $\frac{\text{standard time}}{\text{time actually taken}} \times 100$ per cent. Day rate

is paid for efficiencies lower than 66.6 per cent, and a bonus chart is established, so that when the efficiency is 90 per cent, the premium paid is 10 per cent. At 100 per cent efficiency, the premium is 20 per cent, with a 1 per cent increase for every 1 per cent further rise of efficiency.

There is not the same pull upon the worker to achieve the task as there is in the other two systems. The efficiency is not calculated on each job, but is estimated weekly or monthly to eliminate spasmodic effort and to ensure that the bonus paid corresponds to the average productivity of the worker.[1]

(*d*) MERRICK MULTIPLE PIECE RATE. This also is a modification of Taylor's system in which three piece rates are fixed. When a man's efficiency is less than 83 per cent, his earnings are calculated from a base piecework rate. Between 83 and 100 per cent, this rate is increased by 10 per cent, and when the work is done in less than standard time, a further 10 per cent is added to his piece rate.

(*e*) BEDAUX OR POINT SYSTEM. This is similar in principle to the Halsey Premium Plan in that the worker who does the standard amount of work receives a portion of the saving resulting therefrom. The differences are that the standard task is set by means of time study, and that a special unit of work or effort is used. This is called a "point" or "B," and consists of a certain amount of useful work plus the allowance for rest or delays, the sum of the two being 1 minute. The ratio of useful work to rest or delay in a "point" varies in different classes of work, but in all cases, the standard task is a "60 point hour," or the achievement in each hour of 60 units each consisting of the correct proportions of productive work, rest, and delays. This task is set, as in the Gantt and other systems, so that an experienced man can attain it and earn the necessary premium. General experience is that a good worker will produce from 70 to 80 points per hour, while in exceptional cases, as many as 85 points may be realized. Beginners are usually paid about 85 per cent of the standard rate, but are raised to the standard when they can regularly achieve the set task. Production above the standard is usually paid for as in the Halsey system, 75 per cent of the increased value going to the worker and 25 per cent being put aside for bonuses to foremen, supervisors, and indirect labour,

[1]The "Wennerlund" plan is somewhat similar to that of Emerson. For a detailed comparison of the various wage payment systems see Dickinson's *Compensating Industrial Effort*, Chap. XIII.

who contribute to the increased production. Workers in some of the plants, however, object to the deduction of 25 per cent of their increased earnings for the purpose of paying indirect labour, and hold that this should be paid out of the saving in overhead expenses. In some factories, the worker is paid the whole of his increased earnings, and the premium for indirect labour is paid by the firm.[1]

The "point" standard is the number of points given by the time study for a given job, and "premium points" are those earned in excess of this standard.

Thus, suppose the point standard for a piece is 12, and that the operator produces 45 of these in an 8-hour day. Assume also that two 10 minute rest periods are allowed.

Then the point hour is $\frac{(45 \times 12) + (2 \times 10)}{8} = \frac{560}{8}$ or 70.

The premium points are $70 - 60 = 10$.

For an 8-hour day, the premium points are $10 \times 8 = 80$. If the operator has a premium of 75 per cent and his rate is 60 cents per hour, his total earnings for the day are—

(*a*) Base rate $= 8 \times 60 = \$4.80$

(*b*) Premium $= \frac{80}{60} \times .75 \times 60 = \$0.60$

Total earnings $= \$4.80 + 0.60 = \$5.40$

Actual rate paid $= 67.5$ cents per hour.[2]

In practice, forms are used for posting in the shop the points produced during the previous day, from which each operator can see what he earned on that day. This sheet also indicates the efficiencies of the various workers, and arouses a certain amount of competition between them.

The Hayes "Manit" system is operated in a similar manner, a "manit" being a standard man-minute of work, which is determined by the time study.

(*f*) The "York" Plan which is being used by a number of Canadian firms, is a wage incentive system in which the operator is guaranteed an hourly wage and receives a daily premium in direct proportion to production above standard. These standards are guaranteed and the operator is paid separately for all un-

[1]See *Trans. A.S.M.E.*, Paper Man, 50–8, on "Co-ordinating Wage Incentives and Production Control," by Grothe (and discussion).

[2]For fuller discussion of this system see *Industrial Engineering and Management*, by R. M. Barnes, *Industrial Engineering and Factory Management*, by Anderson, or *Wages and Labour Conditions in British Engineering*, by Yates.

avoidable delays. The "base rate" placed on the job is a guaranteed hourly minimum rate. Standard times, obtained by time study, are expressed in minutes and include the usual allowances. Each day, a sheet is posted in the department showing the previous day's record for each operator. This gives the hours worked, minutes credited, rating and premium earned. Each day is a complete entity and operators are not required to make up losses out of subsequent premiums.

Example. Operator completes 200 articles with a Standard Time of 150 minutes per 100, and 300 articles with a Standard Time of 80 minutes per 100. Machine breakdown of 40 minutes and waiting work 20 minutes are reported. Operator works 8 hours. Base rate is 50 cents per hour.

200 at 150 min. per 100	300 min.
300 at 80 min. per 100	240 "
Machine Breakdown	40 "
Wait work	20 "
Total minutes credited	600

The rating is the ratio of the "minutes credited," over 480 (8 hours) expressed as a percentage.

$$\frac{600}{480} \times 100 = 125 \text{ per cent}$$

or 25 per cent above Standard.

Pay for the day—

8 hr. at 50 cents	\$4.00
Plus 25 per cent premium	1.00
Total	\$5.00

Group Bonuses.

The foregoing paragraphs have indicated methods of inducing individuals to increase their production, but in some cases it is preferable to deal with groups of men or departments as units. Also, most of the methods described above, do not allow for the payment of supervisors or unproductive labour. In one factory, a definite percentage of the value of the monthly output is set aside for distribution in the form of bonus. Superintendents are given 3 to 4 units of bonus, foremen 1½ to 2, and workmen ½ to ¾ of a unit. The value of a bonus unit is determined by the total amount set aside from the articles produced and the number of units to be shared. Thus, there is an incentive towards

increased production and towards reduction of non-productive labour, as the amount of bonus received by superintendents and foremen is lowered if the number of bonus units is large.

Group bonuses are most suitable for work of a continuous nature where the output of one operator is controlled by that of one or more of the others. Co-operation will be increased by fixing a bonus for the work of the entire group, because if one man is in a difficulty, the rest suffer until he gets out of it. Also, the unwillingness of experienced hands to help learners is overcome by this method; but on the other hand, there will be considerable opposition to the inclusion of learners in such groups. The amount of supervision, non-productive labour, and lost time are all reduced in this system, and the clerical work required for costing and time-keeping is simplified.

The total bonus earned by the group is worked out in a somewhat similar manner to that in the case of individual bonuses, the efficiency of the group being $\frac{\text{total standard hours}}{\text{total actual hours}}$. The distribution of the bonus among the men is not so simple, however, as individual shares are not easy to determine.

Lowry, Maynard, and Stegemerten,[1] in describing the system used by the Westinghouse Company, state that each individual's share is dependent on two factors: first, the number of hours that he worked with the group during the pay period, and second, his value to the company. The latter is determined by his skill, length of service, attitude, intelligence, and general characteristics.

The principal difficulties are those of handling jobs which are unfinished at the end of a pay period, and those of checking individual jobs or efficiencies.

The success of a group depends partly on its size. The writers cited above give examples of groups varying in size from two to thirty-five men, but they say that as a general rule, the group should not consist of more than fifteen members.[2]

Profit Sharing and Co-partnership.

Profit sharing consists of giving to employees a share in the net profits of their employers, in addition to their ordinary wages. This is not usually granted as a legal right, but may be continued or discontinued at the employers' discretion. The

[1] *Time and Motion Study*, p. 343.
[2] See also Dickinson Op. Cit., Chap. XIV.

system of Messrs. Rowntree of York, England, divides the surplus remaining after wages, dividends, and reserves have been distributed, in the following ratio: labour receives 50 per cent, directors 10 per cent, and capital 40 per cent. The bonus may be given in cash, in special funds, or in hypothetical shares. These pay dividends, as do the ordinary shares, but as the certificates contribute no capital to the business, the dividend is usually slightly less than that paid on the ordinary shares. The advantage expected, and usually obtained, is greater *esprit de corps* in the business, with a consequent reduction of labour trouble and turnover. The disadvantages are due to—

1. The remoteness of the reward. A bonus that is paid at the end of six months or a year or that may not be paid at all, is seldom attractive to the worker.
2. It is not generally favoured by the trade unions, who claim that attachment to the firm tends to weaken that trade solidarity which it is their business to strengthen.
3. There is no definite incentive to the individual worker, as the lazy man shares equally with the diligent.
4. The amounts to be received are small in the works where such systems are applicable. Statistics[1] show that the ratio of bonus to earnings varied from nothing to 20.7 per cent, the average being about 6½ per cent. This suffers by comparison with direct incentive plans that give bonuses of 25 per cent or more.
5. Good work in the shops may be nullified by bad management and other conditions that are not under the control of the men. Shields expresses this fact in the following words:[2] "In the ordinary business firm, the relation between the individual attention and energy of the employee and the net periodical results of the business is somewhat uncertain . . . he merely contributes to the actual results."

In spite of these disadvantages, however, quite a number of firms have operated successfully under this system for years, and the situation is summed up by Seebohm Rowntree in his Introduction to the *Manchester Guardian's* articles on *Practical Profit Sharing*—

> Two facts emerge from a close examination of schemes of profit sharing and co-partnership which have been put into operation. First, the results have been far more satisfactory than is generally assumed.

[1] "Practical Profit Sharing," *Manchester Guardian*, and Dickinson, Op. Cit. Chapter XVI.

[2] *The Evolution of Industrial Organization*, p. 165.

The popular opinion as to the success of profit sharing is based largely on a consideration of the percentage of the schemes introduced which have been abandoned. At first sight it appears high, and people jump to the conclusion that this is because profit sharing is intrinsically unsound. But closer examination of the facts shows that if you eliminate schemes which were abandoned for reasons entirely independent of the success or failure of profit sharing, such, for instance, as the death of the employer, or amalgamation of the business with another one, it is found that the proportion of cases where profit sharing has proved successful is much larger than is generally supposed.

The second fact which emerges is that in not a few cases where profit sharing is reported to have failed, this is due either to a misapprehension of the ends which it may be expected to serve, or to the neglect of certain conditions which it is essential to observe if the scheme is to meet with the full support of the workers.

These conditions, briefly, are that—

1. The amount of capital which is adopted as the basis of the scheme really represents assets; that is to say, that capital has not been inflated.

2. Labour's proportion of profits is fixed, and the share it will receive cannot be reduced by any manipulation of reserves, or by unreasonable increases in rewards of management, or similar methods.

3. Labour has adequate means of satisfying itself as to the accuracy of the accounts.

4. Labour has a legal right to its share, and is not dependent upon the bounty of employers.

5. There are no unreasonable provisions restricting the mobility or freedom of Labour.

6. Wages are not less than trade union or other appropriate rates.

7. Employees are free to join any trade union.

8. Strikes are not to be penalized.

If these conditions are observed, and if the business is a normal one, it may be safely assumed, on the experience of previous schemes, that results may be looked for satisfactory to all parties.

Profit or gain sharing in its basic form refers to a sharing of the net annual profit of the whole enterprise but a large company with various plants or sections may make the employees' share depend on the profit made by the plant or branch immediately concerned. This is called "unit" profit sharing and it is claimed that it gives the worker an interest in the prosperity of the section in which he works and to the output of which he contributes personally. In some instances also, the profit sharing scheme is restricted to executives and the higher salaried employees.

The object of *co-partnership* is to give the workers not only a share in the profits but also a voice in the control of the business, at least to the extent of their holdings.

The advantages and disadvantages cited in connection with profit sharing apply also to co-partnership schemes, with the exception that the workers now have some measure of control over business policies and the conditions under which they work. The following excerpt from *The Times Engineering Supplement*, 20th May, 1922, indicates that this factor is not so important as it is sometimes considered to be—

Whether democratic control could ever be a panacea for workmen's grievances may fairly be doubted. Unemployment, the gravest of them, is affected by many circumstances beyond the control of the works; but, apart from these, the best chance of the works to avoid unemployment is to make its production efficient, and as a mitigant of unemployment, democratic control must stand or fall with the extent to which it promotes efficiency of production. Experience, again, does not show that individual workers get better conditions or a larger share of the rewards of labour when their employers are of their own class than when they are professional managers of industry; nor when society has appointed tax-collectors, school-board officers, policemen, and magistrates do men seem to like them better or to get more satisfaction from their attentions because their authority has a democratic source, which, indeed, is not always evident when it is being exercised.

Also, the influence of individuality in founding and running a business and the disadvantage of co-operative control are illustrated by the following extract from *Engineering*, 23rd September, 1927—

Again, the various co-operative societies have never earned any extraordinary profits, and their rate of development has been quite slow as compared with successful contemporaneous private enterprises. To earn big profits it is necessary to break new ground and to take risks which only the individual responsible to himself, or to two or three congenial partners, dares venture. Hence, the co-operative societies have founded no new industry, nor have they been responsible for any radical improvement in methods of distribution. They have thus avoided the risk of large losses, but at the same time have failed to reap the extraordinary and well-deserved profits of successful pioneering. In this connection it is interesting to note that the original Bessemer steel works at Sheffield earned on the average 100 per cent every two months during the 14 years it was owned and operated by the original partners. The first two years, however, showed a loss, and though there was a small profit on the third year's operations, it was insufficient to make good the deficit previously incurred. Both exceptional faith and exceptional ability were needed to make the works a success. A similar condition of affairs arose in the case of the early telephones. The stock of the pioneer company could at one time, be bought for a mere fraction of its nominal value, and the individuals who kept their faith and saw the thing through fully deserved their

ultimate high reward. It is quite certain that no exceptional risks will ever be undertaken by firms with co-partnership schemes, and whilst experience shows that they may be very prosperous, they will never show results in any way comparable with those achieved by men like Bessemer, Carnegie, Lord Leverhulme, or Ford.

These questions are also discussed in detail by Dickinson[1] who indicates the difficulties experienced with them in times of depression due to increased unemployment, short time and the fall in the market value of shares. He is dubious as to the desirability of the workers' participation in management, but describes some systems that are in use. Another interesting experiment is that of the Columbia Conserve Company, a small organization in which all the affairs of the company were placed in the hands of the workers[2] with, it is claimed, substantial success. It is questionable, however, whether an equal measure of success would be obtained in larger scale operations.[3]

On the other hand, Spicer[4] claims that "the success or failure of co-partnership schemes, in general, seems to depend upon the extent to which such control is given." "Where the acquisition of shares by the workpeople is unrestricted in amount, and carries with it the normal powers of the shareholder, it tends to be successful. When restrictions are imposed as to the amount of holdings or voting power, it does not."

Richardson[5] states that, at the end of 1936, there were 266 such schemes operating in Great Britain (apart from co-operative societies) of which 176 were started after 1918. They affected about 220,000 employees, or about three times the number of people participating in such schemes in 1913. The average amount of bonus received per employee in 1936 was about $60 or 6.3 per cent of earnings. In some industries, profit sharing and co-partnership schemes appear to flourish, but this report indicates that more than one-half of the schemes started, have been discontinued, most of them after an effective duration of under ten years.

Annual Wages.

One of the most important objectives of labour is the security of income resulting from the payment of annual wages to all

[1] Op. cit., Chaps. XVI and XVII.

[2] See *The Columbia Conserve Company, an Experiment in Workers' Management and Ownership*, by Wm. P. Hapgood, Indianapolis, Ind.

[3] See *Report on Industrial Conditions in Canada and U.S.A.* (1927), H.M. Stationery Office, Appendix V and Appendix XIII, Table IV.

[4] *British Engineering Wages*, p. 98.

[5] *Industrial Relations in Great Britain*, 1938, p. 191.

manual workers. Guaranteed employment of this kind has already been adopted with apparent success, particularly in the reduction of labour turnover and improved morale. The possibility of its wider application depends on the ability of the company to forecast its annual budget, the presence or absence of seasonal fluctuations, proper explanation of the plan to the employees and a thorough study of the plan before it is adopted.

Formulae.

Several of the systems described in the previous pages can be reduced to formulae and illustrated by means of curves. Most of the books and articles dealing with payment of wages use as a basis the total earnings, but as the rate of pay depends on the remuneration received per hour, the hourly rate has been chosen in these examples, and is plotted against the time actually taken to do the work. (Figs. XIV.3. and 4.)

Let the standard rate of pay be C cents per hour.

The standard time for the job S hours.

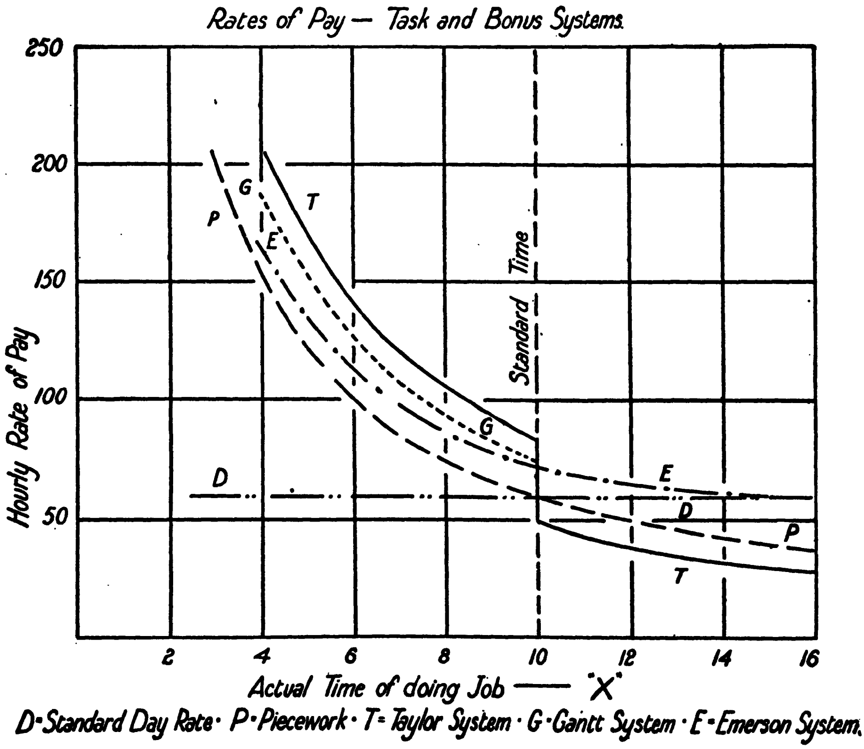


FIG. XIV.4.

The time actually taken to do the job X hours.
DAY WORK. Hourly rate $= C$ cents.
PIECEWORK. Price for job $= SC$ cents.

$$\text{Hourly rate} = \frac{SC}{X} \text{ cents.}$$

HALSEY PREMIUM—

If X is greater than S, hourly rate is C cents.
If X is less than S, assume a premium of 33.3 per cent.

Then hourly rate $= \dfrac{C(2X + S)}{3X}$ cents.

ROWAN PREMIUM—

If X is greater than S, hourly rate is C cents.

If X is less than S, hourly rate $= C\left(2 - \dfrac{X}{S}\right)$ cents.

BARTH PREMIUM—

Hourly rate is $\dfrac{(\sqrt{SX})C}{X}$ or $C\sqrt{\dfrac{S}{X}}$ cents.

TAYLOR DIFFERENTIAL PIECE RATE—

Assume low rate is 75 per cent of standard rate and high rate is 140 per cent.

If X is greater than S, hourly rate is $\dfrac{.75\ SC}{X}$ cents.

If X is less than S, hourly rate is $\dfrac{1.4\ SC}{X}$ cents.

GANTT BONUS SYSTEM—

Assume bonus is 25 per cent.
If X is greater than S, hourly rate is C cents.

If X is less than S, hourly rate is $\dfrac{1.25\ SC}{X}$ cents.

EMERSON EFFICIENCY PLAN—

Efficiency of man is $\dfrac{S}{X}$.

If X exceeds 1.5 S, hourly rate is C cents.
If $X = S$, hourly rate is 1.2 C cents.

If X is less than S, hourly rate is $C\left(\dfrac{S}{X} + 0.2\right)$ cents.

The tendencies of these formulae are shown in Figs. XIV.3. and 4. Here the piecework curve $\frac{SC}{X}$ falls below the day-work rate if the standard time is exceeded, and its form is followed by the Taylor and Gantt curves, and approximately by the Emerson curve. The step that occurs in the Taylor and Gantt curves at standard time illustrates the strong urge put upon the worker to achieve the task, while the mildness of this incentive in the Halsey, Rowan and Emerson systems is indicated by the gradual rise of the curve. The severity of the Taylor system in reducing earnings when the standard time is exceeded is shown by the fall of the right-hand side of the curve below the piecework and day rate lines.

The Rowan system gives a straight-line relationship between time and rate of pay, and it is seen from the curves that it gives higher hourly rates for moderate savings of time, but when considerable savings are made, the Halsey curve rises above the Rowan line. Also, the straightness of the Rowan line shows that there is a definite limit to the hourly rate under this system, and the formula shows that when X is O, the hourly rate is 2 C, or twice the standard rate.

CHAPTER XV

COSTS AND COST KEEPING

General.

The selling price of a manufactured article depends very largely upon the prices at which similar articles are sold by competitors in the same field. The amount of profit obtainable, therefore, depends upon the cost of (*a*) making and (*b*) selling the goods. The conditions in the factory necessary for producing economically have already been outlined in the previous chapters, but after these points have been attended to, it is also necessary to have accurate and prompt returns of the actual costs incurred. The accuracy of such records depends upon the method of obtaining them. These will be discussed later. Promptness is also essential because accurate costs to be obtained in the future are useless as present guides. Therein lies the difference between the accountant and the cost-keeper; the former is interested in the *facts*, the latter is concerned with the *interpretation* of the facts.

A good costing system can do nothing of itself, but if means are provided for interpreting and following up the reports provided, considerable benefits will be derived therefrom. Costs have been described as the "measuring stick" for management, and in fact they do reflect the efficiency of the administration and production arrangements. Factories that operate with an indifferent costing system are working in the dark, as they do not know at any particular time how much profit is being made, or they may be operating at a loss without being aware of it. Even if, by some rough and ready means, they do know approximately their financial position, they can only detect weaknesses in their organization by more or less inspired guesswork.

This situation is by no means uncommon, as is shown by the great variation in tenders for work of which the nature and extent is carefully specified. The difficulty of obtaining accurate costs by means of average figures is indicated by Bentham,[1] who remarked that while his average cost of casting (foundry) was about 55 shillings per hundredweight, he found that the detailed costs varied from 35 to 125 shillings. He instanced the difficulty

[1] *Engineering*, 20th December, 1921.

of getting the costs of intricate castings from a foundry when plain ones were going through at the same time, as showing that a straight tonnage basis was not reliable for costing purposes.[1]

The system of costing employed, therefore, must be sufficiently detailed to indicate the important facts, and not too cumbersome or expensive for practical use. Mathematical accuracy is theoretically possible, but its attainment would involve excessive expenditure and would consume an inordinate amount of time. The system adopted must be suitable for the type of product that is being made, and judgment must be used in laying out the plan of classification, so that the total monies expended will be apportioned correctly among the various products. Unless this is done, some of the articles sold will be debited with more than their fair share of the costs, and the selling price will be too high, with a consequent loss of business. Others will carry less than their share, and will produce less than the anticipated amount of profit, or may even be sold at a loss. For these reasons, it is particularly important that individual costs shall be accurately known before selling prices are adjusted for competitive purposes.

Good costing also indicates the savings made by changes in the organization or by new processes. Operations, such as planning, time study, or mechanical transportation, are not economical unless they pay for themselves, and this can only be known through the cost records. Comparison of departmental or other aggregations of individual costs enables the efficiency of departments to be checked, indicates the cost of labour turnover, and gives other information of a statistical nature. In slack times, these also show where retrenchments can best be made.

Just as standard times are fixed as bases for wage payment systems, so *standard costs* are determined for normal conditions in various departments. Actual costs fluctuate from time to time owing to variation in material and labour costs, and these fluctuations make it difficult to determine business policies. With the standard cost method, the actual cost of any job can be calculated within close limits by applying to the standard cost for that department the ratio of actual to standard departmental cost for that period. This device also assists the manager by calling attention to those variations from standard that he should investigate.[2]

[1]See also *Trans. A.S.M.E.*, October, 1940, p. 590, for an example of an incorrect inference from cost accounts.

[2]See *Budgetary Control and Standard Costs*, J. A. Scott.

The costs are also of vital importance in preparing the budget (Chapter VIII). Past figures of cost are useful for comparative purposes, but the budget must be based on present conditions, and this is an additional reason why cost records should be up to date.

Details.

The total cost of any manufactured product is divided into (*a*) Materials, (*b*) Labour, (*c*) Expense or Overhead. The first two of these are self-explanatory, and the third consists of all those items of expenditure that are not identifiable with the finished job, but are necessary for its production or distribution.

- Production Costs
  - Prime Cost (directly apportionable)
    - Labour Expenditure
      - Moulding
      - Core-making
      - Fettling
      - Metal Melting
      - Sand Preparation
      - General Labour
      - Crane Service
    - Material Expenditure
      - Fuel
      - Metal
      - Fluxes
      - Sand, Plumbago, etc.
      - Metal Melting Loss.
  - Works Production Charges (Some directly apportionable)
    - Supervision
    - Wasters (Scrap)
    - Interdepartmental Transport
    - Inspection
    - Store-keeping Labour
  - On Costs or Overhead Charges (Production shops and offices only)
    - Power
    - Lighting
    - Heating
    - Plant, Fire Insurance
    - Taxes, Nat. Insurance
    - Laboratory Testing
    - Drawing Office
    - Works Management
    - Administration Expenses
    - Repairs to Buildings
    - Repairs to Machinery
    - Depreciation on Buildings and Machinery
    - Interest on Capital
    - Cost Keeping
    - Forms and Shop Stationery, etc.
- Selling Costs
  - Packing and Delivery (Material and Wages)
  - Selling Organization Expenses
  - Selling Organization Offices
  - Overhead Charges
  - Expenses

TABLE SHOWING THE ANALYSIS OF FOUNDRY COSTS

For instance, every factory requires foremen, watchmen, crane operators, labourers, and other general workers; it must be heated, lighted, and supplied with power; rent, taxes, and insurance must be paid. None of these are apparent in the product, but, nevertheless, they are necessary for its existence. Thus, some part of this money must be debited to each of the factory's products. A detailed cost analysis for a foundry is given in the foregoing table, as an indication of the number and kind of items that appear in the final cost.[1]

The *material* cost is usually divided into—

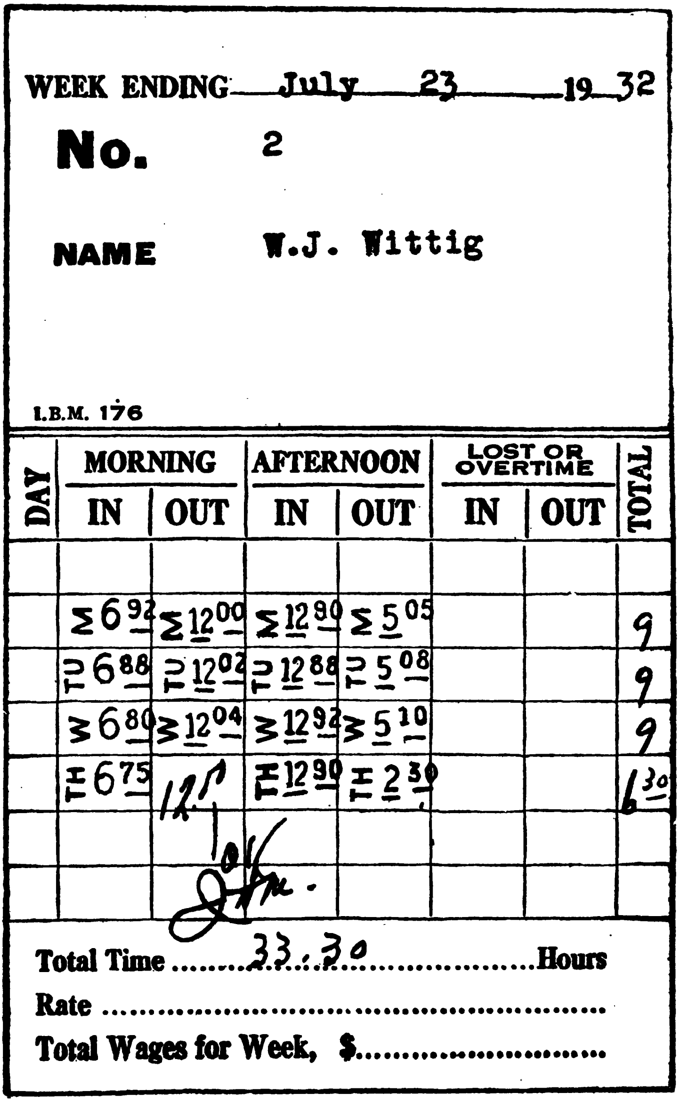
1. *Direct material*, which is all matter that is directly measured and identified as part of the finished job. The quantities issued for each production order may be obtained from the stores' records, but the prices at which they are to be charged depend upon the purpose for which the cost is required. If the object is to fix the selling price, the prevailing market price should be used, but if it is used to balance manufacturing accounts, the original purchase price must be employed. These prices may be obtained from the purchasing, or, in the latter case, from the invoice department. Apart from fluctuations in market price, the value of the material used in any job will be standard, unless a change is made in the design.

2. *Indirect material or supplies*, which consists of all matter which was supplied for manufacturing purposes but which does not appear in the finished job, or which does appear and cannot be measured. Oil and tools are necessary for producing work, paint is used to protect it, fuel is burned in forging or heat-treatment processes, and so on. If a large number of similar articles are produced, the value of these items can be distributed evenly over the quantity made in a given time, but where the output is of a varied nature, some other method may be adopted of prorating this expense over the articles made in the department. If this is not done, the cost of such supplies must be charged to factory expense. It will be indicated at a later stage that expenses or overhead costs are still more difficult to apportion satisfactorily, and therefore it is important that all possible items of material and labour shall be charged to specific jobs.

Labour costs are similarly divided into direct and indirect items.

[1]For a comprehensive survey refer to *Factory Administration and Cost Accounts*, by E. T. Elbourne (Longmans Green & Co.), Section VI.

3. *Direct labour* is charged to the appropriate job number by the use of time sheets and cards. A card or time check is used to indicate the time of entering or leaving the works (Fig. XV.1.), and formerly each man had a time sheet upon which he entered the number of hours spent on each job. This gave rise to very inaccurate labour costs, as, although the totals for each week were correct, the apportionment was very haphazard.



WEEK ENDING July 23 19 32

No. 2

NAME W.J. Wittig

I.B.M. 176

DAY	MORNING IN	MORNING OUT	AFTERNOON IN	AFTERNOON OUT	LOST OR OVERTIME IN	LOST OR OVERTIME OUT	TOTAL
	M 6 92	M 12 00	M 12 90	M 5 05			9
	TU 6 88	TU 12 02	TU 12 88	TU 5 08			9
	W 6 80	W 12 04	W 12 94	W 5 10			9
	TH 6 75	12	TH 12 90	TH 2 30			6 30
		10					

Total Time ....33.30.... Hours

Rate ....

Total Wages for Week, $..........

Fig. XV.1. Weekly Time Card

Some of the men did not fill in the times as they completed the jobs, but left them to be filled in from memory at the end of the day or the week. Others, who were given to loafing (or soldiering), would fill in extra time on any job that they considered would stand it. Thus, any big job that stood in the shop

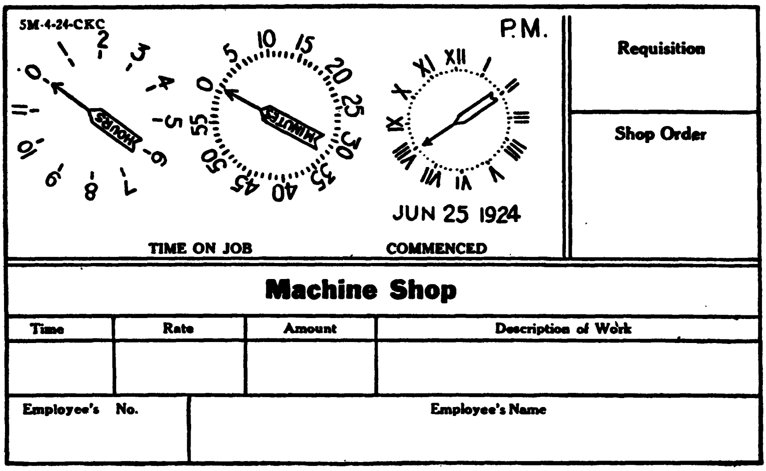


FIG. XV. 2. JOB TICKET

for several weeks was likely to be the repository of many of these "unearned increments," and its cost was inordinately increased. Of course, the foreman should check this practice, but he cannot be everywhere and watch everything.

A better method, where conditions warrant its adoption, is for the operator to receive a job ticket, an example of which is shown in XV.2. The time of commencing each job is stamped on the face of the ticket, and the elapsed time is the difference between the times stamped on successive tickets. In some systems, the sum of the elapsed times taken from the job tickets is checked with the times given on the time cards.

4. *Indirect labour* is not directly chargeable to the job and so is sometimes included in the "factory expense," but as in the case of indirect material, it is preferably apportioned among the various jobs in the department. This may be done by means of regular or special *standing orders* to which a man engaged on non-productive work may be instructed to charge his time. Such orders are those relating to maintenance or repairs of various kinds, shop cleaning, material handling, and any others that may

be suitable, but the number should not be too great, as otherwise the resulting complication may produce confusion.

Overhead.

The difference between the total cost of the article as delivered to the customer and the prime cost (material plus labour) is called variously overhead, expense, burden, or "on" cost. This contains all of the items that cannot be definitely allocated to material or labour and, as it is very difficult to apportion correctly, the amount of money in the overhead expense should be reduced to the smallest possible proportions.

It consists of two kinds of expense—

(*a*) *Constant* items, which are necessary for the existence of the business and remain at the same level whether the production is high or low. Such expenditure as rent, taxes, insurance, and interest is always present whether the works are operating or not, and these form the constant part of the expense.

(*b*) *Variable* items, which depend on the volume of business done and are roughly proportional to it. The expenditure on fuel, power, lighting, and maintenance will increase as the work becomes heavy and will decrease in slack times.

Overhead expense is also divided according to its source into *factory and selling expense.* The former includes all items of cost up to the delivery of the finished part to the stock room or shipping deck; the latter consists of such items as advertising, travellers' salaries and expenses, transportation, etc.

Factory Expense.

The principal difficulty in spreading this cost over the individual items of production is due to the large number of variables that are liable to affect this distribution. For instance, a large and heavy casting or forging will absorb proportionately more time and labour from crane-men and other general workers about the shop. Then also, the large machine tools cost more to operate, and both they and the casting or forging occupy a large amount of space on which rent has to be paid. Maintenance and repair charges occur periodically, but they must not be debited entirely to the work that is in the shop when the repairs are made. Obviously, these should be spread over all the work done in that section in proportion to the time taken by each job. In other cases, intricacy or complexity may influence the overhead cost. A small machine, consisting of numerous delicate parts, will absorb more of the supervisor's time than will one of greater

simplicity or ruggedness. It is practically impossible to take into account all of the various factors and to distribute them justly over the output, so the system adopted must be a compromise, giving costs that approximate sufficiently close to the truth for engineering and commercial purposes.

The following methods of distributing factory expense are used in practice—

1. DIRECT MATERIAL BASIS. In this case, the expense is distributed over the whole of the output for the same period. This method is only suited to continuous industries that always produce the same kind of material, such as brick or cement plants. If the product varies, the relation of overhead cost to output is not constant, and some other method must be used.

2. DIRECT LABOUR BASIS. This is a very common method of handling overhead cost in engineering works. It consists of adding a percentage (say, 100 or 150 per cent) to the direct labour costs to take care of factory expense. As the ratio of overhead to labour cost varies in different classes of work, it is usual to employ different percentages for pattern shop, foundry, machine shop, and fitting shop, respectively. This method makes no allowance for the time element, unless the men are paid by time. Also, if business falls off in one or all of the products made by the factory, the ratio of overhead to labour cost is changed, so that accurate costs can only be obtained when wage rates are fairly uniform and the shops are operating at a reasonably constant load. Even under these conditions, it is difficult to take machine costs into account. One operator may use only hand tools and another may use an expensive miller or grinder; the labour cost is possibly the same in these two cases, but the overhead cost is very different.

As an example of the variable nature of the relationship between factory overhead and direct wages, the following average figures (p. 237) for various classes of engineering work have been taken from the bulletin on unemployment issued by the Engineering and Allied Employers National Federation in 1933. These refer to Great Britain during the period 1926–1931, and are included for comparative purposes only.

3. PRIME COST BASIS. This method uses the material plus labour, or prime cost, as a basis for distributing overhead expense. It is seldom used because the ratio of material to labour cost varies considerably in different classes of work.

Kind of Industry	Material Percentage	Wages		Factory Overhead	
		Direct Percentage	Indirect Percentage	Percentage of Total Cost	Percentage on direct Wages
Electrical........	43.9	17.6	16.7	18.6	105
Foundries.......	33.1	30.1	16.5	19.4	65
Locomotives.....	46.7	28.6	20.8	22.8	80
Tools...........	29.2	24.7	13.3	25.2	102
Marine..........	51.5	24.2	13.2	15.8	65
Textile..........	30.1	41.9	16.6	26.5	63
Automobiles and aircraft....	45.9	16.8	15.1	17.1	102

4. MAN-HOUR BASIS. This basis is the number of hours spent on a job. It differs from the direct labour method in that it depends on time only, and does not include differences due to the various rates of pay. However, as pointed out above, in most cases time is only one of the contributory factors. With this system the others are ignored.

5. MACHINE-HOUR BASIS. This amounts to rent paid for the use of the machine during the time spent on each job, the charge per hour being based on the size and value of the equipment. It includes such items as interest, depreciation, maintenance cost, floor space occupied, power used, and cost of attendance. Such a system is suitable for shops having a high percentage of machine work and a relatively small amount of hand work, but there still remains the difficulty of allowing for idle time.

Under the best conditions all of the machines are never working all the time, and therefore a percentage of idle time must be allowed for in each case. When the final costs are completed, it may be that the actual percentage of idle time is greater or less than that assumed. As far as the department or shop is concerned, these gains or losses may cancel out, but the actual cost of individual jobs will still differ from those estimated, and the profits made will be more or less than those anticipated. It is impossible to change accomplished facts, and these discrepancies must be charged to profit and loss. If the production is for stock, such a loss may be absorbed by adding a supplementary machine rate, but this is seldom known in sufficient time for adjustments of this kind to be made. Some items of expense, however, bear no relation to the cost of operating the machine, and consequently, the machine rate basis is often supplemented by other departmental and general expense rates which take care of such factors.

PRODUCTION CENTRE METHOD. This was devised by Church[1] to avoid some of the difficulties mentioned in the foregoing paragraphs. The production centre idea has already been outlined in Chapter XI. Each of these forms a convenient sub-factory to which the proper proportion of the overhead costs can be allocated by the use of various factors.

Those relating to lighting, heating, rent, etc., are proportional to the floor area occupied by the production centre. The power absorbed by each centre and the cost of maintenance may be determined in most cases, and interest, depreciation, etc., are generally functions of the capital cost. This is really an adaptation of the machine rate method, and as in that case, supplementary rates are usually necessary to take care of other expense items. A serious difficulty is the cost of making the initial study, and in this, as in all other processes, it is necessary to inquire whether the greater accuracy obtained is sufficient to compensate for the extra accounting cost.

Selling Expense.

The difficulty of distributing selling expense is similar to that of allocating factory expense. The cost of selling a product frequently bears no relationship whatever to the selling price. A $10,000 machine may cost less to sell than one worth $500. The method of basing selling costs on prices might easily result in failure to get an order for the former and in making no profit on the latter.

When products of a varying nature have to be sold, the first step is to determine the amount of selling expense to be borne by each of them. This is not always a constant quantity, however, as some articles are easy to sell in one locality and difficult to sell in another. Bassett and Heywood[2] suggest that the most nearly accurate method for handling items of selling expense is on the basis of cost per call, and for this purpose, accurate and complete reports must be compiled by salesmen. The number of calls possible in a densely-populated district is greater than those in a rural district, and the cost of making a call is less in the former case than it is in the latter. Thus, the selling costs must be compiled both by products and by districts, and these should be approximately uniform for any district. They will have to be revised from time to time to take account of changes in travelling costs. Packing and shipping costs and the distribution of ad-

[1]See *Manufacturing Costs and Accounts*, by A. H. Church.
[2]*Production Engineering and Cost Keeping*, p. 291.

vertising expense come within this category. They may be analysed in a similar way unless they are of such a nature that they can be charged directly to a particular kind of product.

The following remarks on distribution costs are taken from a paper by Knapp[1]—

> Distribution cost is a most important factor in almost every type of business endeavour; whether retailing, jobbing, or manufacturing. The dollar used by the ultimate consumer in making his purchases is a totally different one from the one manufacturers use in their computations. It is cut down to perhaps 75 cents when considered from the jobber's point of view, and perhaps 60 cents when reduced to the manufacturer's standpoint, or expressed inversely, the manufacturer's sales dollar becomes \$1.25 to the jobber and \$1.666 to the retailer. These comparisons will, quite naturally, change with the nature of the business. In 1931 the distribution cost in the drugs and toilet-articles manufacturing business was 38.8 per cent of the net sales. Some of these products are sold to jobbers who sell to retailers who in turn sell to the ultimate consumer. Assume a jobber's gross profit of 15 per cent, out of which he has to pay all expenses of doing business and make a net profit, and assume a retailer's gross profit of 25 per cent, out of which he has to pay all expenses and make a profit. Based on the distribution cost of 38.8 per cent, if a manufacturer wishes a profit of 5 per cent on net sales, a toilet article with a manufacturing cost of \$1.00 becomes a sales dollar of \$1.78 to the manufacturer, a sales dollar of approximately \$2.10 to the jobber, and a consumer sales dollar of \$2.80. Think of it—an increase from a manufacturing cost of \$1.00 to a purchase price by the consumer of \$2.80, and the manufacturer has made only a 5 per cent net profit while the jobber and the retailer are having a difficult time in making any profit at all. One then says that the cost for distributing the product is too high. Very probably, but the drug manufacturer's advertising and salesmen's expense alone were 30 per cent of his net sales but, if he did not advertise his product, the consumer would not know of it, and the jobber would not carry it.

This indicates the fact that in some branches of industry the distribution costs form a very substantial part of the selling price and must be analysed and scrutinized accordingly. This paper gives additional details for the cigar industry.

Depreciation and Obsolescence.

The fact that articles diminish in value with age and use (unless they are old enough to be called antique) is a matter of common knowledge, and this depreciation is a factor that must be taken into account when costs are compiled. A machine made to-day will be of less value in ten years' time, even though it is unused and in perfect condition, because in the meantime, it has

[1] *Trans. A.S.M.E.*, May, 1936, Paper MAN, 58-2.

become old-fashioned or it has been superseded by more convenient or efficient models. The machine may have a normal life of twenty years; yet, after five years, it may be valueless apart from the scrap value of the metal contained in it because nobody would be willing to purchase it, or because it has become too expensive to operate under the changed competitive conditions. This is called "*obsolescence.*"

Depreciation in value, due to wear and tear and similar causes, is offset to some extent by repairs and maintenance, but even so the machine or building will become useless after some years. The life of buildings or shop equipment is difficult to estimate. Much depends on the amount of money spent in maintaining and protecting them and on how much they are used. Machines that are habitually run at heavy loadings for long working periods will be worn out before others that are lightly loaded or less frequently used. Barnes[1] gives a list of the average lives and rates of depreciation that may be used for average conditions, but these are subject to adjustment in special cases. Generally, physical decay and decrepitude vary with time, but other forms of depreciation are not constant, the rate being rapid at first and then gradually becoming less. The reduction in value of an automobile is a case in point; the loss is heavy for the first year and decreases as the machine becomes older. Each type of equipment and construction will have a different rate of depreciation. A book or card record should be kept, giving the purchase price and date, the estimated life and rate of depreciation for all equipment. The form of the depreciation fund and the method of distributing depreciation over the estimated life of the equipment are matters that call for careful consideration.

One method is to take the difference between the initial and scrap values of the equipment and to divide this by its estimated life, thus giving a constant rate of depreciation. If, however, these depreciation funds are invested, either in securities or in the business itself, the investments will accumulate interest which must be added to the fund. Annuity tables may be used to determine the sum that must be set aside each year to realize the total amount of depreciation at the end of the estimated working life. This is called the "*sinking fund*" plan, but it fails to indicate the present value of the equipment in case of a forced sale.

[1]*Industrial Engineering and Management,* Appendix C.

Another scheme (called the "reducing balance" method) is to take a fixed annual percentage of the diminishing value, a greater amount being charged off at the beginning of the period than at the end. The initial cost, taken as the basis for all of these methods, must include the value as installed and ready for work, including all accessories. In addition to the depreciation of buildings and equipment, a further percentage must be agreed upon for obsolete or unsaleable stock.

A fourth method which appears to be gaining popularity is the "Present worth of probable future returns" formula.[1] This involves a periodic re-estimate of the probable life and usefulness of the equipment and produces a discontinuous line when value is plotted against time, instead of the smooth curves characteristic of the first three methods.

The depreciation of textile machinery described by Benoit[2] produced a discussion,[3] a great part of which is probably applicable to manufacturing plants generally.

Questionnaires were sent to 763 plants representing approximately 30,000,000 spindles, and 255 mills representing 14,500,000 spindles replied in sufficient detail to be used for statistics. The figures quoted below are from this compilation of data—

90 per cent use the straight-line method of computing depreciation.

8 per cent use a composite rate for all depreciable assets.

63 per cent use a composite rate for all machinery, including power plants and separate rates for buildings according to classification.

18 per cent follow the last method with a separation of power plant.

9 per cent use a complete classification of depreciable property with classified rates.

This last is the most accurate for cost purposes; the more simple methods are no doubt used for convenience in accounting even though the cost department has to break the figures down into more detail for cost purposes.

It was also stated that out of 255 plants reporting, 89 per cent charged repairs and supplies direct to operating expense, which indicates a preponderance of opinion in favour of this procedure.

The application of these factors to the selection and replacement of equipment, as illustrated by the woodworking industries,

[1]See "Some Misconceptions in Engineering Economics," by C. R. Young. *The Canadian Engineer*, 30th March, 1937.

[2]*Mechanical Engineering*, December, 1933, p. 732.

[3]*Mechanical Engineering*, March, 1934, p. 179.

was described by Norton,[1] and from this paper the following example has been extracted—

Let—

I = the investment in present or proposed equipment.
For proposed equipment this should be the total cost in place ready to operate, and for present equipment it should be the present net realizable value, regardless of the book value.

A = annual percentage allowance for return on invested capital.

B = annual percentage allowance for taxes, insurance, etc.

D = annual percentage allowance for depreciation and obsolescence.

Y = annual total fixed charges = $I(A + B + D)$ dollars.

C = annual total cost of upkeep or maintenance, dollars.

E = annual total cost of power, supplies, etc., dollars.

F = annual total cost of space allotted to machine, dollars.

M = annual total cost of material, dollars.

L = annual total cost of direct labour, dollars.

T = annual total cost of indirect labour, dollars.

R = annual total charges of all kinds against machine for producing expected output. $R = Y + C + E + F + M + L + T$.

A furniture manufacturer requires an additional machine for a certain operation. Two machines are being compared, one costing $1,226.00, which has just the capacity required at present, and the other an automatic machine costing $2,864.00, which has twice the capacity required at present. No credit will be given the automatic machine for its extra potential capacity. The machines will be compared on the basis of a five-year life, and a 12 per cent return on average investment. Insurance and taxes will be figured at 3 per cent. Here

$$A = \tfrac{1}{2} \times 0.12 \times \frac{5+1}{5} = 0.072$$

$$B = \tfrac{1}{2} \times 0.03 \times \frac{5+1}{5} = 0.018$$

Factor	*Hand Machine*	*Automatic Machine*
I	$1,226	$2,864
A	0.072	0.072
B	0.018	0.018
D	0.20	0.20
$A + B + D$	0.29	0.29
Y	1226 × 0.29 = 355	2864 × 0.29 = 830
C	50	25
E	193	250
F	15	21
M	—	—
L	1,857	680
T	—	—
R	$2,470	$1,806

[1] *Mechanical Engineering*, October, 1934, p. 589.

The figures in the above table indicate that even with the automatic machine idle half the time there will be a saving in total charges of $664 per year. It can be easily shown that if the automatic machine were compared with two hand machines, for full operation of the automatic, the saving in total charges would be $2,179 per year. No credit was given the automatic machine for potential capacity which cannot be used at present. This is conservative practice, but it is evident that if the total charges on this basis had been approximately equal, this extra potential capacity—an intangible factor—might have been the deciding element.

Waste, Spoilage, and By-Products.

Waste consists of material left over unnecessarily from the manufacturing operations. Some excess material is unavoidable and this may be called "scrap." It has a market value which can be credited to manufacturing processes. Waste, on the other hand, has no market value and represents a loss. The cost-keeper should keep a special account of these items to determine whether or not the amount of waste or scrap is excessive and whether it is preventable or not.

Spoilage is due to bad work. It represents a loss both of material and labour. It may be handled either by charging the good pieces produced with the whole cost of the lot (including the spoiled articles, less their scrap value) or by charging the cost of replacement.[1]

By-products, such as the tar, coke and commercial liquor produced in gas-making, have considerable commercial value. They are credited to the manufacturing account after the cost of preparation has been deducted.

Miscellaneous.

Rent paid for buildings or equipment must be debited to the manufacturing cost. This must be distributed in an equitable manner over the various buildings in the plant. If the firm owns the land and equipment, *interest* must be distributed in the same way. The reason for this is that if the capital were not invested in land and buildings it would bring in a corresponding return from some other investment, so that no profit should be calculated until this interest has been deducted from the returns. *Taxes* and *insurance* should be handled in a similar manner.

The greater incidence of overhead costs on the output when part of the factory is idle is a matter that demands consideration. If these are handled by simply absorbing them in the cost of manufactured products, the causes of idleness and the amount

[1]See *Manufacturing Costs and Accounts*, by A. H. Church, Chap. IX.

of it will not be apparent. Lansburgh[1] advocates listing them directly under a separate heading, such as "idleness expense," so that attention may be directed to this factor and the necessary remedial action taken.[2]

Checking.

The accuracy of the costing system can be checked in several ways. The total costs of producing the same machine may be compared at different periods, or the variation of cost with size may be plotted. In other cases, costs per unit of weight may be used to compare machines that are of similar or of different weights. Thus, a large and heavy machine should cost less per pound of weight than a small one of the same type, and if the records do not show this, there is something wrong. Some firms use a balanced cost system in which various agreements, which prove the accuracy of the records, are secured.[3]

Profit.

A manufacturer must make a profit, otherwise, sooner or later, his business will cease to exist. The fact that he owns a business, however, is no reason why he should make a profit. He must render some service to the community from which the profit comes.

Thus Alford states the law of profit: *A steady and reasonable profit can only come as the reward for rendering essential service.*

The amount of profit obtained depends largely on manufacturing costs and competitive selling prices, but where the latter are controllable, a fixed percentage added to the cost of production would mean that a greater amount of profit would be obtained where the production cost was high, thus penalizing efficient management. Goods made in large quantities may be sold with a smaller percentage of profit on account of the greater aggregate profit obtained. Shields[4] discusses the possibility of the State control of profits or prices, and indicates the difficulty of this procedure on account of the large number of variables involved. The first difficulty is that of determining a "reasonable" rate of profit, in view of the fact that some firms have special gains due to superior management or patent rights. Also, many businesses are over-capitalized, due to amalgamations or

[1] *Industrial Management*, p. 494.

[2] See also Gantt's argument as given in Jones' *Administration of Industrial Enterprises*, p. 354.

[3] See *Manufacturing Costs and Accounts*, by Church, p. 279–282.

[4] *The Evolution of Industrial Organization*, p. 98.

absorptions, or promoters' profits being unduly high. The net profits are further influenced by allocations for depreciation or reserves, usually settled by the management. He concludes that "like other forms of State intervention in industry, there are obstacles to its introduction and operation, but it has the advantage of giving recognition to the fact that companies should not be solely interested in the making of profits and the payment of dividends."

CHAPTER XVI

INDUSTRIAL RELATIONS AND PERSONNEL

Industrial Relations.

The importance of the human factor in industry cannot be overestimated and this fact is indicated by the ever-increasing attention that is being directed to the relationships between management and employees. Dirks[1] lists the essentials of a sound personnel relations programme as follows—

(1) *Competent management*, which inspires respect and improves morale.

(2) *A definite personnel policy*, stated in writing, to guide all members of management in their relations with employees.

(3) *Competent personnel staff.*

(4) *Effective employment and placement programme*, to select the right kind of workers for each kind of job.

(5) *Adequate training*, to fit the selected worker for the job and to ensure that he understands it.

(6) *Sound wage administration*, giving a fair day's pay for a fair day's work and recognizing individual merit.

(7) *Defined upgrading programme*, to give promotion in accordance with ability and to prevent favouritism.

(8) *Good working conditions*, as efficiency is closely associated with comfort and safety.

(9) *Good grievance procedure*, providing for prompt consideration and final settlement of problems.

(10) *Regular inter-communication*, to keep workers properly informed regarding the policies and activities of the organization.

Such matters as insurance plans, disability payments, social services, medical services, thrift plans, vacations and pensions may be included under the general heading of "welfare work."

Swift[2] states that what the employee wants is—

(1) To be considered as an individual, not as part of a mass.

(2) To feel that he has a dignified part in a worthwhile enterprise.

(3) To have the opportunity to express himself about things that are going on about him, without creating resentment.

(4) To receive a good pay check; that is, one commensurate with his worth and with that received by others for equivalent work.

(5) To be let alone to live his own life (though, once this right is recognized, he is usually willing to accept help offered tactfully).

[1] "Proceedings of the Personnel and Industrial Relations Conference" (1946), Engineering Extension Department, Purdue University (Series No. 59).

[2] "What's New in Personnel and Industrial Relations" (1940), Engineering Extension Department, Purdue University (Series No. 48).

At the same time the rights of employers should be recognized. The Canadian Manufacturers' Association[1] has issued the following statement of policy with regard to employee-employer relations—

A. Both Employees and Employers Should—

(1) Regard continuity and quality of service to the public (the customer), as the first consideration. Upon it depend year-round jobs, good wages, dividends, and the future of Industry itself.

(2) Observe faithfully the provisions of every agreement or undertaking made by them or on their behalf.

(3) Seek constantly to discover methods of increasing production and improving products.

(4) Consider with open minds proposals made by either party to the other, each seeking to understand the other's needs and problems, and constantly bearing in mind that neither can operate without the assistance of the other.

(5) Settle differences by negotiation in good faith without interruption of operations.

B. Employers Should—

(1) Provide facilities which will permit efficient and economical production and make all reasonable provision for the safety and health of their employees during the hours of their employment.

(2) Select and develop supervisors who are not only technically competent, but who will deal on a fair and friendly basis with the men and women whom they supervise.

(3) Respect the right of employees to associate freely for all lawful purposes.

(4) Bargain collectively, in cases where representatives have been freely chosen by a majority of the employees affected, on wages, hours of work, and working conditions.

(5) Organize operations with a view to promoting maximum regularity and continuity of employment and consequently maximum stability of income.

(6) Give employees, as far as possible, opportunities to progress within the organization according to ability, experience and merit.

(7) Support and develop good wage standards having regard to all circumstances which are material.

Employees Should—

(1) Recognize the Employer's right to plan, direct and manage the business.

(2) Perform their assigned duties in an efficient and industrious manner to the best of their ability.

(3) Co-operate freely with management in meeting the many problems in which the employees are concerned.

(4) Conserve and protect the products, plant, equipment and machinery, and respect the rights, of employers as the owners of the property.

[1] "An Approach to Employee-Employer Relations" (1946), Canadian Manufacturers' Association, Toronto.

(5) Recognize the right of an individual employee to join or not to join any lawful organization of employees or other citizens without impairing his right to work at the occupation of his choice.

The difficulty of getting precise information on various matters by using ordinary scientific test procedures was illustrated by Entwistle[1] in describing the experimental work at the Hawthorne plant of the Western Electric Company. It was found that variations in work behaviour, even under controlled conditions, were caused more by variations in personal attitudes than by changes in the physical conditions of work. It was also found that, when workers from a particular locality or group were interviewed, certain ways of thinking and reacting had some common denominator for that group or locality. In one group, at least, there was a sort of informal organization that had a considerable influence on the behaviour of the employees in that part of the factory. Some of their objectives were in opposition to those of the management, and their function was to give the group a sense of security. As a consequence, the controls instituted by the management did not work out in the way management assumed they did. It was found that more could be learned by allowing employees to talk than by actively interviewing them—this procedure seemed to provide an emotional outlet that must necessarily be provided when personnel counselling is attempted. The research showed that the employee is seeking more than a financial reward from the job. He must be given an opportunity to justify his existence and to earn the respect and appreciation of others.

Morale scales, attitude analyses and questionnaires are now used to discover the state of morale in an organization and to reveal latent problems before they become serious[2] and in some instances have provided useful information.

Labour Turnover.

"One of the most important tasks of industry in Canada today is to keep employees on the job and to reduce the high costs of labour turnover. Forty to sixty employees out of every hundred have changed occupations during the past twelve months. . . . A survey of 250 war and essential civilian industries in Canada showed that turnover is not confined to estab-

[1]"Non-directive Personnel Counselling," A. W. Entwistle. (Paper presented to the Industrial Relations Committee of the Engineering Institute of Canada, November, 1945).

[2]See *Personnel Management and Industrial Relations*, by Dale Yoder, (Prentice-Hall).

lishments that pay low wages. Industries of better than average salary suffered a loss of employees between 30 and 110 per cent annually."[1]

These remarks apply specifically to war time conditions but the causes alleged, namely, poor housing, unsatisfactory family life, transportation difficulties, poor laundry service, unsuitable or inadequate food and lack of security are important contributory factors in the post-war period.

With the older systems of management, hiring and firing were entirely under the control of the shop foreman, who was concerned solely with the successful running of his own department and had little or no idea of the wider economic problem. This has two aspects, the first being industrial and the second national, and they correspond roughly with the following two laws[2]—

1. LAW OF LEARNING[3]

Under usual conditions, an average worker acquires skill rapidly during the first half of the training period, then more slowly for a time, if at all, and finally at a rapid rate until average proficiency is attained.

2. LAW OF INDIVIDUAL PRODUCTIVITY

The highest individual productivity is possible only when the worker is given the highest class of work for which his natural abilities fit him.

The former of these laws shows that whenever a worker changes his employment a period of instruction is necessary, during which money must *be spent upon him by the firm*, both in supplying the necessary measure of instruction and also by reason of loss of output during the learning period. This money is either partly or wholly lost when the worker leaves his employment, and it is therefore advisable that the initial investment should be spread over the longest possible period of years, so that the *annual* outlay for this purpose may be as small as possible. It was estimated that the loss due to this factor alone varied from $8.50 to $200 for each man hired, the average being about $150. Multiply this figure by the number of employees hired, and the resulting sum represents a considerable drain on the income derived from trading.

[1]Thomas Brook in "Manufacturing and Industrial Engineering," September, 1944.

[2]*Laws of Industrial Management*, Alford.

[3]See also *The Acquisition of Skill, an Analysis of Learning Curves*, by J. M. Blackburn, H.M. Stationery Office, 1936.

The second law indicates the importance of *suitable* work being obtained for each employee. The "trial and error" method frequently used not only raises costs and decreases production by increasing labour turnover, but also creates serious social problems due to "misfits," because many of those actually employed are not suited to the class of work upon which they are engaged. If, as stated in Chapter XIV "the normal wage level of each country depends upon and corresponds with that country's general average productivity of labour," it follows that a high percentage of "misfits" in any industry automatically reduces the possible wage level. The importance of a sound method of selecting workers is thus apparent.

Causes of labour turnover are classified by Kimball as—

Due to *Employee*	Due to *Employer*
Incompetence	Low wages
Insubordination	Bad working conditions
Laziness	Poor safety arrangements
Drunkenness	Injustice
Roving Disposition	Inefficient Management
Misfortune	

"To these must be added such factors as the fluctuating character of some industries and the seasonable demand for certain products for which neither employer nor employee is to blame."

For comparative purposes, it is advisable to have a definite method of stating labour turnover. Two different methods are in use, one being the ratio of the number *hired*, the other being the ratio of the number *leaving*, to the average number on the payroll in any given period. Some companies use both, but in any case it is advisable to dissect the total turnover for the factory into percentages by departments or shops, so that any abnormal conditions may be easily located.

A detailed study of labour turnover in the United States during the period 1913–18 was made by Brissenden and Frankel.[1] This period was rather abnormal, as it included the war years, but many of the conclusions are applicable to industry generally. They suggest that—

(*a*) The labour *flux* should be stated by adding together the numbers hired and fired during a given period. The rate of *replacement* is evidently the smaller of these two quantities.

[1]*Labour Turnover in Industry* (Macmillan Co., 1922). See also *Personnel Management and Industrial Relations*, by Dale Yoder (Prentice-Hall) 1943, pp. 270–282.

(*b*) For statistical purposes, a relatively constant base may be obtained by using the number of 3,000 hour workers (300 days × 10 hours) to which the total working hours put in during the period are calculated to be equivalent. Some of the indications of this analysis are—

(1) The effectiveness of a liberal labour policy and centralized employment systems in reducing labour turnover.

(2) Assuming that the irreducible minimum is about 25 per cent of the work force, the percentage of unnecessary labour changes ranges from 54 to 86 per cent of the labour changes which have actually taken place.

(3) The rate of turnover shows a downward tendency as the size of the organization increases from below 1,000 to over 5,000 employees.

(4) Most of the turnover occurs in the first few months of employment, e.g. 38 to 83 per cent of the new men hired left within one year; also 60 per cent of those leaving had less than three months' service.

(5) The rate of labour turnover was greater among *male* than among *female* workers, greater for *night* than for *day* shifts and greater among *unskilled* than among *skilled* workers.

(6) The greatest rate of turnover occurs during the period March-May in each year.

Methods used for reducing labour turnover are suggested by several of the causes tabulated above, and others will be indicated in the following paragraphs.

Absenteeism or lost time is frequently closely associated with excessive labour turnover and may indicate the preliminary symptoms of that disease. An analysis of the causes of lost time in the United States gave the following reasons:

	Per cent		Per cent
Sickness	17.7	Not given	6.0
Hangover	12.2	Long working hours	5.8
Irresponsibility	10.7	Seeking job	5.5
Business	7.3	Shopping	4.5
Weather	7.1	Working conditions	2.9
Family visit	7.0	Sufficient money	2.8
Transportation	6.4	Not interested	2.3
		Seeking house	1.8

During World War II considerable study was given to this problem and appropriate remedies were applied where possible.

Charts showing the number of days lost per week or month and the consequent loss of production were prominently displayed and one Toronto firm reported a reduction of absenteeism of 30 per cent after adopting this procedure. Another reported a reduction of lost time from 2.9 per cent of the total to 1.08 per cent at the end of a three months' campaign. These methods were devised for war-time use but evidently some of them might be employed with advantage at other times.

Unemployment.[1]

The increased efficiency of industrial operations and the transfer of skill from men to machinery has intensified the unemployment problem, especially in times of depression.

It has been estimated[2] that the national income in the United States was reduced by unemployment to the extent of 14.5 per cent in 1930, 28.5 per cent in 1931 and 42 per cent in 1932. Also that from 1930 to 1937 inclusive the total loss from this source was 204.7 billions of dollars or more than twice the income of any year during this period. Workers in the coal, clothing, and building trades were idle from 30 to 39 per cent of the time.

The causes of unemployment are given by Meeker as follows—

1. Lack of planning of production to meet and not to exceed consumption requirements.
2. Faulty distribution and utilization of the national income, causing alternating periods of over-saving and over-investment in production or intermediate goods, accompanied by under-spending and under-consumption of immediate or final consumption goods, followed by over-spending and under-saving.
3. Wide variations in the general price level, which means changes in the purchasing power of money.
4. Unforeseen calamities, including marked over-production of some commodities, as well as destruction of lives and goods by earthquakes, floods, storms, droughts, famines, etc.
5. Technological improvements due to new machines, methods, management, and organization.

All of these causes amount to a lack of balance between production and consumption.

The fifth of these contributory causes has received considerable publicity, but most of the arguments which purport to

[1]For details of the Canadian situation see the "Interim Report of the National Employment Commission," Ottawa, 1937.
[2]"Monthly Labour Review" (U.S.A.), November, 1939.

show that the depression of 1930 to 1934 was principally caused by technological unemployment are of very doubtful value.

In examining this question, it is but fair to note that the majority of those who write and speak on the subject appear to have little or no knowledge of any manufacturing industry. They apparently nourish their doctrine on two delusions: first, that most things are now made by the same methods as those on which motor cars are made in Detroit; and second, that during the last ten years there has been a sudden and remarkable increase in the application of mass production methods. On the first point it is only necessary to say that mass production, in any proper sense of the term, is in the main confined to new industries which would never have come into existence on their present scale if methods of that kind had not been developed. These methods are confined to relatively small articles required in very large quantities, and so far from causing unemployment have, by making such articles available at moderate prices, created new markets and new employment on a very large scale.[1]

A survey of the Unemployment situation in Great Britain (1933)[2] showed that unemployment was *highest* in those trades where there had been the *least* amount of mechanization, and *lowest* in such industries as automobile building and electric lamp making, where the amount of mechanization was *greatest*. It was also proved that in 1929 the total number of workers employed was greater than in any pre-war year, and that the percentage of women employed in industry had not changed appreciably between 1901 and 1921, in spite of the replacement of men by women during the war years.

An examination of American figures also indicates the fact that mechanization does not produce permanent technological unemployment, whatever its temporary effects may be.[3]

The Census of 1900 lists the number of workers in the shoe-making industry, both handicraft and factory, as 153,600, and gives their earnings as $63,304,344, or about $415 per person. This industry has been very fully mechanized, yet in 1914 the number employed was 191,555 with average earnings of about $522 per person. In 1925 there were 206,992 workers in the industry with total earnings of $225,-787,981, or about $1,090 per person. The purchasing power of the dollar of 1925 was about 66 per cent of that of 1914 and 53 per cent of that of 1900, but even with these allowances there has been a gain in real wages since 1900. Furthermore, in 1900 there were 4,849 children under 16 years of age employed in the industry with yearly earnings

[1] *Engineering*, 6th January, 1933, p. 17.

[2] *Unemployment, its Realities and Problems*, Engineering and Allied Employers National Federation.

[3] "The Social Effects of Mass Production," by D. S. Kimball, *Mechanical Engineering*, February, 1933. See also "Labour Displacement by the Machine," *Engineering* editorial, 26th March, 1937.

of about $177 per year per child. No such conditions are tolerated to-day in progressive states.

Again, in the printing industry, which also has been highly mechanized, the Census of 1900 gives the number of workers as 162,992 with yearly earnings of $84,249,963 or about $517 per person. The census of 1925 lists 251,276 persons as employed in this calling with total annual earnings of $438,832,974 or about $1,746 per person. Here again, allowing for the difference in the value of the dollar, there has been a decided gain in earnings. Furthermore, such statistics do not take into account the increased employment due to the production of machinery for these industries. In 1925 the value of the printing machinery produced in the United States was $69,216,683 and the corresponding value of shoe-making machinery was $11,769,137, and each of these machine industries in turn has many ramifications, the money value of which would be difficult to compute.

Dr. Karl T. Compton,[1] President of the Massachusetts Institute of Technology, states that "statistics show no decrease in the fraction of our population gainfully employed during the past few generations in which machine production has become important." This was illustrated by the effect of mechanical refrigeration on employment among ice dealers, which was more than doubled between 1920 and 1930, also by the motion picture industry and many others.

Dr. C. F. Kettering says that 25 per cent of all workers in American industry owe their jobs to eighteen new industries developed as a result of research since 1880. He says also that the trouble with America is not over-production of goods but under-production of new ideas.

Cameron[2] indicates that in 1938, the number of people employed in making motor cars (U.S.A.) was 306,000, but that the indirect effect of this industry was to provide employment for 6,380,000 other persons. Hoffmann[3] gives the following statistics for the Studebaker Company—

Year	Number of Employees	Average Yearly Wage	Hours Worked per Week	Value of Sales per Employee
1870	300	$465	60	$1,550
1908	3,000	$624	60	$1,986
1936	7,337	$1,698	40	$9,175

[1] *The Valve World*, July–August, 1939.
[2] Radio Address, October 29, 1939.
[3] *Manufacturing and Industrial Engineering*, November, 1937, p. 13.

Another analysis of "Machines and Working Hours"[1] shows that during the period 1929–35 employment per dollar of finished product (U.S.A.) increased 28 per cent in manufacturing industries, 38 per cent in refrigerating machinery, 41 per cent in household laundry equipment, and 31 per cent in stoves and furnaces. In 1899 there were 4.7 million workers averaging 56.8 hours per week with 2.11 h.p. of machinery per worker. In 1937 there were 8.5 million workers, averaging 39.8 hours per week with 4.86 h.p. of installed machinery. The glass industry employed 13 per cent more people in 1939 than in 1929, at an average wage of $1,300 per annum.

The Unemployment report referred to above also indicates that the increased output of goods by mass production has the result of increasing employment in other ways, and this accounts for the misleading effect of figures based on single industries.

In taking a long view of this matter, the following points should be remembered—

1. The expansion of employment in industry which has resulted from *increased demand* stimulated by the cheapening and increasing of production as a result of the use of machinery.
2. The expansion of employment in the *distributive trade* as a result of increased production.
3. The expansion of employment given by the increased *production of raw materials*, the manufacture of *machinery* and the harnessing of *power*.
4. The expansion of employment as an indirect result of the *expenditure of the comparatively high earnings* of mechanized industry *upon the products of industries supplying consumable goods*.
5. The expansion of, or at least the maintenance of, employment in particular industries when by the introduction of some mechanical invention *that industry has been enabled to compete successfully with its rivals*.[2]

This is not the whole story, however, and an example of the manner in which higher operating efficiency increases unemployment is given by McCarthy[3]—

An example taken from the experience of a woodworking plant employing less than 400 men will make the problem of the displaced worker in depression specific. The engineers found that specialization of effort, the introduction of piecerates, and a small amount of machinery reduced the labour required 40 per cent. Of the 100 cabinet makers formerly in the department, 40 were no longer required. These 40 men were released to find work elsewhere and the pay of those who

[1] *Manufacturing and Industrial Engineering*, October, 1938, p. 7.
[2] *Unemployment, its Realities and Problems*, p. 39.
[3] Industrial Efficiency and Economic Equilibrium," *Mechanical Engineering*, March, 1932.

remained was increased as much as 25 per cent, leaving the remainder of the saving to be distributed between ownership as increased profits, and the general furniture-consuming market as reduced prices. From the social standpoint this solution of the problem was extremely incomplete. The 40 men must eventually compete in the labour market with the 60 who remain, and thereby reduce wages to a figure lower than ever if this condition is general in all industries.

The 40 men are problems, for it is foolish to assume, if the histo y of the 1921–1930 period means anything, that they have but to go around the corner to find other work. In the first place, some of that work is no longer to be had. In the second place, years of specialization as cabinet makers, ownership of real estate, education of children, family tradition, old age, attachment to environment, all resist the easy flow of labour from one job to another. Can a small reduction of price to each of the thousands who make up the furniture-using market be looked upon as an equitable compensation for the difficulties of the 40 men and their families, especially when it is entirely probable that many of the ordinary manufacturing economies entirely disappear before reaching the ultimate consumer because of the many hands through which the product must go, jobbing house, wholesaler, retailer?

Technological changes tend to displace employees in present industries and to find employment for them or others in new industries and so increase the extent of labour turnover. By threatening the security of workers they tend, therefore, to produce fear and unrest and a demand for some form of employment security.

This problem cannot be solved by the provision of assistance by the State, as charity is a temporary palliative which in the long run destroys self-respect and makes the recipient a parasite upon society. Hook[1] comments on this in the following terms—

Society, therefore, is seeking better ways of rendering assistance to its needy, placing the burden where it belongs and in a manner that will not create unfavourable reactions that in themselves may offset all of the good done.

There is probably no single social phenomenon that has a more destructive effect upon the mental attitude and morale of its victims than that which causes people to be thrown out of employment. It wrecks plans, weakens ideals, checks ambitions, and arouses bitterness and criticism that go far to undermine our social system. Every man and woman has a deep-rooted feeling that he or she has the right to earn a living by legitimate toil. Willingness to toil presupposes jobs. When jobs are not to be had, society is accused, and, regardless of logic or argument, must accept the responsibility.

He further divides the unemployed into three classes—

1. Unemployable.

[1] "Industry's Obligation to the Unemployed," *Mechanical Engineering*, October, 1931.

2. Unstable or nomadic workers.

3. Stable employees, who have established positions in the community and are essential to the success of industry in normal times. (This group, in the depression of 1931, he estimated at 40 per cent of the unemployed.)

He argues further that industry is not responsible for furnishing a livelihood for the first class and is only partly responsible for the second, but that it should provide for the third. For this purpose, a system of records was set up to segregate the stable workers. A study of the situation revealed the fact that the reserve necessary to take care of these for one year would have amounted only to three quarters of one per cent of the payroll for the years 1923 to 1929, inclusive. It is not contended that these figures are at all representative, but they are intended to show what can be done by industry itself, in some lines at least, to reduce the unemployment problem.

Seasonal industries, in which the demand varies consistently in different parts of the year, were the subject of a symposium by the American Society of Mechanical Engineers in December, 1930[1]. A number of examples were given to show how the sales curve can be made more uniform, or how careful planning of production can be used to stabilize employment. Among the methods employed were—

1. Developing new uses or changing the form of the product to promote a constant demand.

2. Cultivating a foreign market with opposite seasons.

3. Introducing a new line of product, which enjoys a busy season when the regular product is dull (e.g. many firms in Canada supply ice and coal).

4. Getting orders in early—this is risky when fashions change rapidly, as in clothing, etc.

5. Manufacturing for stock in the dull seasons—this involves storage and spoilage costs, and the danger of over-production.

In the same symposium, Meeker advises the inauguration of three major policies for the amelioration and prevention of unemployment.

(*a*) Planning a consumption-production programme in all industries for several years in the future, so as to minimize or eliminate over-production or under-consumption. This should include a more equitable distribution of the products of industry; that is, the national money income.

[1]See *Trans. A.S.M.E.* Paper MAN., 53–7.

The curves shown in Fig. XVI.1. show how product reservoirs have steadied production and employment for the Eastman Kodak Ccmpany and Proctor and Gamble Company. The provision of suitable storage facilities in these cases enabled production and employment to be maintained at a steady level in spite of the seasonal sales peak. In the latter firm guaranteed employment has been maintained for 21 years.

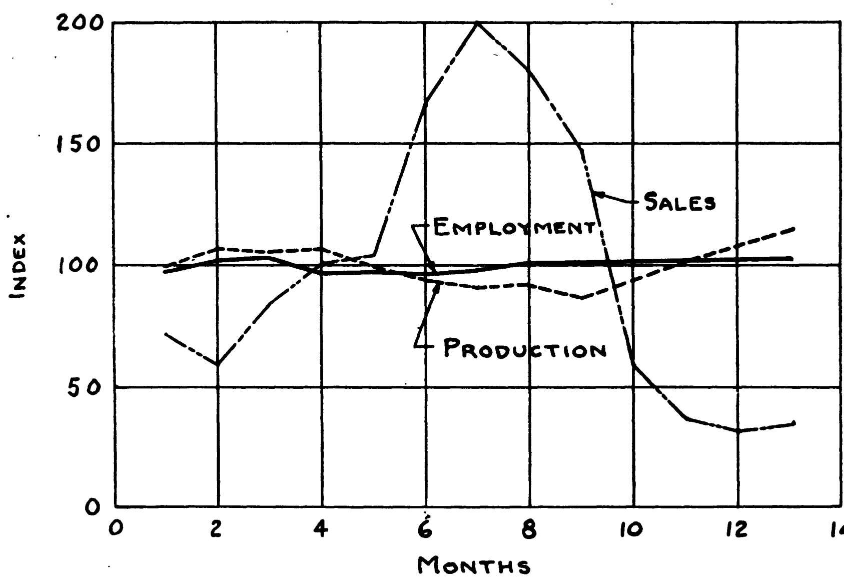


FIG. XVI.1. FLUCTUATING SALES AND STEADY EMPLOYMENT

(*b*) Stabilizing the general price level; that is, the buying power of money.

(*c*) Providing carefully planned, all-inclusive unemployment insurance to prevent unemployment, as well as to take care of the unemployed.

Other possible alternatives are the introduction of a new industry (e.g. radio, or motion pictures, as in Hollywood), or the following example taken from the report on "Industrial Conditions in Canada and the United States"[1]—

An outstanding example of the improvement made possible by a higher management technique is to be found in the building industry. In a large number of districts there is co-operation between builders, architects, and owners by which the programme of building is so regulated as to make the best use of the labour available and to counter-

[1]H.M. Stationery Office, 1927, p. 85.

act climatic difficulties. Also, as a part of the architectural planning, a schedule is prepared settling the dates on which the various classes of work on buildings are to be begun and completed. The deliveries of material and the labour force are settled ahead as far as possible to fit this schedule. By arrangements with architects and owners, there is co-operation in the adjustment of the labour force so that work on different buildings is speeded up or slowed down with the object of keeping workers regularly employed. Artificial heat is used during the winter for inside work. The result has been to add greatly to the amount of employment of the average building worker, which is now about 190–200 days per year, and to reduce costs. Another result is to avoid the losses which would otherwise occur from any waste of the time of highly paid workers, and it would appear that building costs are at a level which compare favourably with those in Great Britain while wages are much higher.

During periods of depression the method of curing unemployment that is usually proposed is to spend large sums of money on public works.[1]

The first consideration in the minds of those who propose these works is the spending of money, so that wages may be paid to the many men who are to be brought into employment. The second consideration is the choice of some work, which but for the present urgency of finding employment, would probably come at some future date. It is argued that in choosing the work to be done we must not put someone else out of work. This way of looking at matters is entirely wrong. The main object in view should be to create as much wealth as possible with the least expenditure of money, and instead of employing as many men as possible on some particular job, one should employ as few as possible on that job, there being no limit to the number of men who can be employed, because there is no limit to the work waiting to be done.

In deciding on the work to be done, *we should not choose work that is not pressing*, as is so commonly the present practice. The raising of money by loans or taxes to do work that is not pressing has the effect of *increasing unemployment, because it takes money away from people who would otherwise spend it on things they want and puts out of work the people who would ordinarily be supplying those things.* Instead of getting real wealth (that is, things that we need), we get only prospective wealth which we cannot immediately use.

The work to be chosen in order to create real wealth can be broadly divided into two classes: (1) the manufacturing of machinery and facilities for creating the articles that we need, and (2) the manufacture of the articles that we need. This paper will deal mainly with the first class, although, as I have said elsewhere, there is a great deal of work waiting to be done which falls under the second class. The people of this country (Great Britain) lack material comforts—houses, furniture, clothing, household utensils, and the tools and machinery for manufacturing these and other things in immense quantities. They also lack

[1] "Engineering Works of Profit as a Cure for Unemployment," by Prof. Miles Walker (British Association, Section G, 1933) *Engineering*, 22nd September, 1933.

food and many of the amenities of life. Provide them with all these things, and they can do without money. Money may be regarded as a kind of receipt for work done.

The alternative to the voluntary assumption of a system of unemployment insurance by industry appears to be its compulsory adoption by social legislation. The latter method has been tried in England since the passing of the Insurance Act in 1911. In this scheme, the employer, employee and the State all contributed to the fund from which unemployment payments were to be made, but there has been little opportunity of seeing whether the system would work well in practice. The advent of the war and the abnormal post-war conditions caused payments to be made that were not contemplated in the original scheme, and as a result the fund was no longer on an actuarial basis. It was not, strictly speaking, an insurance fund at all, but was a form of state relief.

Any insurance scheme that is to be something more than charity must stand upon a contributory financial base. The basic principle of all work insurance is that it will provide a subsistence protection to the great body of workers during temporary interruptions in their regular employment. It was on this principle that the British scheme was enlarged, between 1911 and 1920, to include all manual workers, except those employed in agriculture and domestic service, and all non-manual workers earning less than $1,250 a year.

During the decade or more that unemployment there has been chronic, leaving thousands out of work for two-, three-, and five-year periods, the insurance scheme all but floundered. Trying to see the disaster as temporary, Governments arranged "overdraft" benefits, and continued to pay the "dole" long after the workers' claims had expired. By 1931 the fund was behind $575,000,000, and going further into debt at the rate of $5,000,000 a week.

In the criticism made of the scheme's operation it was claimed that insufficient time had been allowed for the accumulation of resources. The size and proportions of the contributions, the "too wide" extension of the scheme were other points for the fault-finders. Actually none of these had any great bearing on the problem. Simply, the number of unemployed and the duration of their unemployment over-taxed the capabilities of the fund.

The stabilizing influence of jobless insurance cannot be debated. Britain is the proof positive. But at the same time it must be recognized as a limited field. The Unemployment Assistance Board, consequently, exists and spends a quarter of a billion dollars because insurance is not, as so many seem to think, the end of all unemployment troubles.[1]

[1]Editorial from *Globe and Mail*, Toronto, 9th February, 1937.

Unemployment insurance came into operation in Canada on July 1st, 1941, under the terms of the Unemployment Insurance Act of 29th July, 1940. The relative contributions average about 30 per cent from the employees, 40 per cent from the employers, and 30 per cent from the Government.[1] The following table gives a summary of the weekly contributions and benefits.

This scheme is designed for stable employees and does not include permanent governmental or civic workers, or those in domestic service, nursing, travelling and sport. No one is eligible for benefits until he has paid contributions covering 180 days' work in two years (this period is extended in case of disability) and no benefits are payable for the first six months. The rates may be amended at some future time if the fund proves to be insufficient.

Class	Earnings in a Week	Weekly Contributions		Weekly Benefits (If in same Class for 2 Years)	
		By Employee	By Employer	Single Persons	Person with One or More Dependants
0	Less than 90 cents daily (or under 16 years of age)	—	27 cents	—	—
1	$ 5.40 to $ 7.49	12 cents	21 "	$ 4.08	$ 4.80
2	$ 7.50 to $ 9.59	15 "	25 "	$ 5.10	$ 6.00
3	$ 9.60 to $11.99	18 "	25 "	$ 6.12	$ 7.20
4	$12.00 to $14.99	21 "	25 "	$ 7.14	$ 8.40
5	$15.00 to $19.99	24 "	27 "	$ 8.16	$ 9.60
6	$20.00 to $25.99	30 "	27 "	$10.20	$12.00
7	$26.00 to $46.19 (or under $2,400 per annum)	36 "	27 "	$12.24	$14.40

If unemployment insurance were undertaken and operated entirely by industry, it would be free from political manipulation, and the added cost in normal times would probably be slight. As Dr. Meeker points out, "the notion that the whole cost of unemployment insurance would be an added cost upon production is absurd." This assumes that unemployment now costs nothing, whereas all firms are paying for it in the form of taxes. The actual expenditure would consist of the *difference* between the cost of unemployment under the insurance plan and under no plan at all.

A paper by Hook[2] explores the possibility of setting up un-

[1]Abstract from *Canadian Machinery and Manufacturing News*, June, 1941.
[2]"Unemployment Reserves," *Mechanical Engineering*, July, 1933.

employment reserves such as have been suggested above. He estimated roughly that with a reserve of $75 per employee over $1,000,000,000 would have been available, in the United States, for use during the depression of 1930–32.

How far would this have gone toward offsetting a reduction in the national income of $11,000,000,000 in 1930, $29,000,000,000 in 1931, and $41,000,000,000 in 1932, over that established in the normal year of 1925?

At first glance, one would say that the effect would have been very small if, indeed, there had been any effect at all. But that would not be a true statement. One billion dollars distributed in small amounts among many people would not add merely a billion dollars to the national income, but probably ten times that amount. It would be used to buy goods over and over again as it passed from one pair of hands to another. It is not the actual money in the country that represents the national income. Rather, it is the rapidity with which that money is used. If a silver dollar passes among one hundred hands in a year's time, it has negotiated one hundred distinct payments. If, during those passages, it paid wages five times and yielded, say, 10 per cent profit to the recipient every other time, it actually served to increase the national income by fourteen and a half times its value. In 1925 there was never more than $5,000,000,000 of currency in circulation in the country at any one time. Yet the national income amounted to $81,900,000,000, showing that actual cash in use in the country, by supplying the base for checks and drafts, was used about sixteen times. In 1932 the ratio had dropped to approximately seven times.

Personal Characteristics.

The source from which the supply of labour is obtained and the method of selecting men for definite jobs have a considerable influence on the degree of realization of these ideals. Intelligence is always desirable, while work involving severe manual labour requires a corresponding degree of physical fitness. Tests of various kinds have been developed for ascertaining the personal characteristics that are the most suitable for various classes of work. These will be described later, but, in many cases, trial and error is the prevailing method of selection. Such characteristics as honesty, sobriety and industry can only be ensured by inquiry into the previous history of the applicant.[1]

Thus, each job for which workers are required should be represented by a *job specification* card. Upon it the nature and conditions of work and the qualifications required in the operator are stated in more or less detail.

[1]The procedure and organization required for this purpose are described in detail in *Personnel Management*, by Scott, Clothier, and Matthewson (McGraw Hill Co.).

A typical job questionnaire employed by a Canadian firm for office workers contains the following sections—

(1) Job description in more or less detail.

(2) Type of office equipment used (name or description of machine).

(3) Basic minimum education required.

(4) Previous experience normally required (time).

(5) Extent of supervision applied to worker on job.

(6) Amount of checking and effect of errors.

(7) Personal contacts with associates, superiors, customers, etc.

(8) Does the job involve access to confidential data?

(9) Working conditions.

(10) Nature and extent of supervisory duties (if any).

The qualifications of the applicant are then compared with the job specifications, so that the successful applicant will have as many as possible of the characteristics indicated by the questionnaire.

The next step is to train the man to do the best work of which he is capable. This is partly done by instruction, as detailed in previous chapters, and such instruction should include, as far as possible, information which will enable him to visualize the part that his particular operation plays in the whole scheme. Such understanding will create interest, and will mitigate the monotony of repetitive work. A spirit of co-operation and team play is frequently engendered by means of a factory magazine, or other publication, and this is often used for educational and social purposes by the larger firms.

Records of efficiency are useful not only as a basis of payment, but also for reference when promotions are being made or when reductions of staff are necessary. In a small works, such problems are solved by the manager or foreman, who has a personal knowledge of nearly all the employees, but in a large factory, this is impracticable. It is an important factor in the case of a firm manufacturing a variety of articles, where some departments may be busy and others slack. In the latter case, first the poor, then the medium and lastly the good and valuable workers will be "laid off" from that particular department, while few or none may be discharged from other sections of the works. Thus, while each department retains its best servants, the company as a whole is not reducing its staff to the best advantage. These difficulties may be met by a system of efficiency records and

inter-departmental recommendations, but the latter are seldom successful, as the departmental head is liable to take the attitude that the applicant cannot have been so very good, or his previous foreman would have kept him. The best remedy is to have an employment manager in sole charge of employment work in all its phases.

Employment Department.

The somewhat tardy recognition of the high cost of labour turnover, and the development of the functional idea, led to the centralization of employment work and the formation of employment departments. The scope and duties of this department and its head are described in the following extract[1]—

The most efficient procedure is to place all dismissals, as well as appointments, entirely in the hands of the employment manager, who should be trained in this work. He should also have a wide knowledge of the trades carried on in the factory, and must necessarily be of at least equal status to the departmental managers. It is a distinct advantage if he is of higher status, as any possible friction between him and the departmental managers may then be avoided. This arrangement can be carried out quite consistently with the maintenance of full discipline and authority on the part of the departmental managers and foremen, for, in case of insubordination, it is provided that the employment manager must cause the dismissal of the offender from the department unless the departmental head himself agrees to re-engage him. In other cases the employment manager must be consulted before action is taken, so that, in the event of a dismissal being proposed by the departmental head and refused by the employment manager, the individual concerned would know nothing about it. Of course, in a large concern, even the employment manager would not know every employee, and he would almost certainly accept the verdict of the departmental officials as regards efficiency. His function, in practice, is thus to help good men about to be dismissed from a department by effecting a transfer for them to a more busy one. It very rarely happens that he is found thwarting the will and influence of the departmental heads. It is even found safe to allow all employees a right of appeal to the employment manager in case of dismissal. This is seldom used, but it sometimes has the advantage, if dismissal is due to insubordination, of enabling an old hand to plead long service and offer an apology. It then frequently happens, especially in the lower grades, that the foreman dismissed the man in a moment of wrath and is only too glad of an excuse to take him back without loss of dignity. In the case of the higher grades, it prevents victimization due to personal antagonisms, which are sometimes the cause of considerable hardship to a good servant.

The employment manager, then, has a difficult task to perform, and it might appear, at first sight, as though his existence would be only a

[1] "*The Times*" *Engineering Supplement*, November, 1921.

disadvantage, as tending to secure regulation by one who does not know the individuals with whom he is dealing, as compared to a departmental chief who does know them. This objection, however, does not hold, because the employment manager has freedom to ascertain the opinions of departmental chiefs, and this it is his duty to do.

It is also desirable that the employment manager, or his assistants, will have had some shop experience, so that in addition to the information supplied by the job specification card they will have personal knowledge of the qualifications required for the various jobs.

Vacancies are filled on receipt of a requisition signed by the head of the manufacturing department concerned. A statement on the requisition as to the cause of the vacancy will indicate whether or not the employment department is functioning in a satisfactory manner and whether the various jobs are being filled with suitable men.

Applications for employment may be personal or written, but in either case a fairly comprehensive record should be made as soon as the applicant is employed.

In some instances, the employment manager also supervises welfare work, but if the firm is a large one, he will rarely have time to handle both functions.

Vocational Guidance and Employment Tests.

Many young people drift into industrial work for a variety of reasons; because their fathers are thus engaged, because their friends are able to procure jobs for them, or because of financial difficulties at home. They often grow up to be inefficient or embittered workers, because they have been thrown into trades for which they have little or no aptitude and in which their remuneration will always be small. If they realize this before it is too late to make a change, there is still the loss to industry due to labour turnover, and this is frequently repeated several times within a few years.

A great deal of research has been done along the lines of vocational guidance, and bodies have been appointed by the state in several countries to give advice and information relative to the choosing of suitable employment.[1]

Psychological and physiological tests have been devised to test individual characteristics that are applied in industry. These tests and the results obtained from them have received

[1]See *The Evolution of Industrial Organization*, Shields, Chap. VI.

wide publicity, but their application to industrial conditions is subject to considerable difficulties.[1]

Most writers on this subject emphasize the fact that, while testing plays an important part in the selection and placement of employees, their function is supplementary to other selective processes. They cannot take the place of good judgment on the part of the personnel officials, as many of the variable factors cannot be assessed satisfactorily by this means. The tests must be carefully selected, administered and interpreted, otherwise the results will be misleading. Before being adopted as a standard, the test battery must be calibrated by following up the records and performances of those who have been evaluated by that means.

Standard tests have been devised to indicate aptitude or ability, interest and proficiency or achievement. Intelligence tests are designed to measure ability to learn and have been widely applied. Personality tests are sometimes used in the selection of employees who have to meet the public or who have to work as members of a group or team.

Trade tests or performance tests are frequently used for simple operations and serve to show whether the applicant's claims of experience are justified, but they do not indicate whether the applicant will develop into a good and steady worker under unaccustomed conditions.

Taylor[2] describes three steps in the selection of personnel—

(*a*) The weighted application blank or personal history analysis;

(*b*) The personal interview, intended to indicate the characteristics that are best suited for the job;

(*c*) The employment test, which must be reliable and valid. Reliability means that the test must always produce the same result when applied in the same way. Validity means that the nature of the test must be suitable for the job in question. Most tests fail on both of these counts but extended experience is gradually improving the results obtained by them. Mr. R. C. Fuller of the Aluminium Company of America[3] states that, in their experience of 600 men selected on the basis of such tests, only seven were discharged for unsatisfactory work and that, in

[1]See also Yoder (Op. Cit.), Chapter 8, Bethel, Atwater, Smith & Stackman *Industrial Organization and Management*, pp. 469–473, and *Psychology for Business and Industry*, by Herbert Moore (McGraw Hill).

[2]"Selection of Subordinate Personnel," *Mechanical Engineering*, November, 1941.

[3]*Engineering Bulletin*, Purdue University, November, 1940.

general, those with higher test grades were more successful than the others.

Physical tests to measure the physique and general health of the employee and his sight, hearing and other characteristics required for the job in question are obvious necessities. Apart from other considerations they are usually a prerequisite for admission to pension and insurance plans. Visual skills are frequently important in accident prevention[1] and in certain inspection operations. Colour perception may be an important factor as was discovered in a tailoring department where an expert repairer was given the job of repairing a black garment and used a bright red cloth for the purpose—he was colour-blind!

Promotions.[2]

One of the greatest inducements to an able and ambitious man is the possibility of bettering his condition, and for this reason a properly developed system of promotion (or transfer) is an important factor in personnel relations. One of the criticisms levelled by the United States Commission on Industrial Relations[3] against Scientific Management was that it "has developed no efficient system for the placing or adaptation of the worker; is inclined, in practice, to regard a worker adapted to his work and rightly placed when he succeeds in making the task; tends to confine the mass of the workmen to one or two tasks, and has afforded little opportunity, therefore, for the discovery and development of special aptitudes among the mass."

Also, "the employer is loath to take a man from a task where he is making a high efficiency record, and the man or woman whose record is not good is more surely destined to a less skilled and perhaps narrower task." It is a fact that the narrowness of outlook fostered by lack of education and by highly specialized work is scarcely a good training for executive positions. Functionalization of foremanship may well be a necessity under these conditions.

The question then arises as to the best promotion policy. If workers are promoted within the shop, they have the advantage of knowing the work, but it may be difficult for them to maintain discipline without friction among their old shop mates. Also, a

[1]See "Vision Testing in Industry," by Tiffin and Long, Purdue University Bulletin No. 59 (1946).

[2]See Scott Clothier and Matthewson, Op. Cit. for promotion system and chart.

[3]*Scientific Management and Labour*, Hoxie, p. 92.

consistent policy of this kind promotes "in-breeding" of ideas; it is sometimes necessary to import men from outside, to prevent stagnation. In some instances, it is preferable to promote a man by transferring him from one department to another. By so doing some of these difficulties are avoided.

The report concludes that "*properly applied*, scientific management more fully and speedily separates the efficient from the inefficient worker and affords speedier and more certain promotion and advancement to the former than management of the ordinary kind. It cannot, however, greatly enlarge the field for promotion, and in practice, the methods of promotion and advancement vary greatly in character and merit with the individual shop management."

Where suitable methods are available within the factory or in its vicinity, courses are devised for the purpose of educating men. This, added to their natural ability, will fit some of them to occupy higher positions as they become vacant.

Discipline and Disputes.

The substitution of several bosses for one, in the functional method of organization, almost inevitably raises questions of divided authority and unnecessary interference—"no man can serve two masters." On the other hand, the setting of a definite task to be performed in a standard manner reduces the opportunities for autocratic and arbitrary control. The men will stick to their work because it pays them to do so. If the tasks are set too high, however, supervision becomes more intense, and the worker is nagged at and punished to ensure their fulfilment.

A large class of men requires no disciplinary measures at all, but some mistake kindness for weakness, and with them sterner measures must be adopted. These include discharging, suspending, or fining the delinquent. The first two penalties are very severe, and are only adopted under exceptional conditions. If the men be fined the money should be paid into some benevolent or insurance fund, so that the men will not feel that the firm is making money by penalizing them.

Autocratic control of industry breeds disputes and strikes. Filene[1] states that most employers believe in the right of private property to such a degree, that they consider that society should only touch it to the slightest possible extent, after having first recognized and acknowledged that it was interfering with the

[1] "Why Men Strike," *Industrial Management*, December, 1922.

rights of the employer or owner. This amounts to setting up property rights as superior to personal rights, and constitutes an appeal to society to safeguard selfish interests against the common interests of society. This develops an autocratic spirit which is resisted by the men. They feel compelled to fight, by strikes or by using other methods, for a greater share in the control of industrial conditions.

The basic causes of most strikes are fear and injustice. Most workers are afraid of financial insecurity in misfortune, ill health or old age, and all feel resentment, and act accordingly, if they consider that they have been dealt with unjustly. Time lost from work stoppages in Canada reached a record in 1946, being 4,529,424 man-work days as compared with 1,457,420 in 1945. Also, in the United States from the end of August, 1945 to January, 1947, there were 4,630 stoppages affecting a total of nearly 5,000,000 workers. The situation in the coal mining industry of Great Britain (1944) and the importance of strikes in basic industries to the public at large is indicated by the following excerpt[1]—

In the May issue of "The Ministry of Labour Gazette" the tale of strikes and lock-outs in 1944 is put on record. It is satisfactory to learn that most of the stoppages of work during that year were of short duration and involved relatively few workpeople. The really black spot was, as is well known, coal mining. In that industry no fewer than 1,253 stoppages began, no fewer than 568,000 workpeople were involved in all stoppages in progress throughout the twelve months, and no fewer than 2,480,000 working days were lost. That is a terrible record and the end of its repercussions cannot yet be seen. Engineering came second on the black list of 1944, but was only one-fourth as bad as coal. In all other industries the year was fairly good.

It is interesting to note that, taking all industries, only a little over 52 per cent of the stoppages turned on wage questions, that "hours of labour" accounted for less than 3 per cent, and that *rules, discipline,* and *working arrangements* were the cause of *over 30 per cent* of all the stoppages. A table shows that more than one-half of all stoppages ended in a resumption of work on the employers' terms, without negotiations, whilst two-fifths were settled by direct negotiations between the parties or their representatives.

If there is one privilege more than another to which trade unions are attached it is the right to strike, but a change of thought in this respect seems to be called for. There was a time when the employer was regarded as the sole adversary of the strikers, but in all industries, public or not, it is quite clear that *wages must be drawn from the selling price of the goods produced or the services rendered.* It is the purchaser who pays them. We have all of us had that brought home to us in a

[1] "The Engineer," June 15, 1945, p. 470.

hundred ways during the past few years, but in none more personally than in the increased costs of coal getting, which were immediately reflected in a rise in the cost of domestic coal and of commodities derived from it. The fact is incontestible that wages are always paid by those who buy the products of labour. It matters not whether 15 per cent of the production cost is expended on labour, as in the motor-car industry, or 30 per cent, as in heavy engineering industries, it is the purchaser who has to provide the money. Hence, we submit that *no longer can trade unions escape responsibility to the public by claiming that their concern is only with their employers.* They are in fact, whatever they may be in name, public servants. Their action may be beneficial to the community as when, at the beginning of the war, they agreed to sacrifice some of their privileges, or disadvantageous, as when they strike against the advice of their leaders, or obstruct the improvement of shop methods, or keep wages high by restrictive practices.

Employers cannot afford to neglect or ignore just causes for dissatisfaction among employees, any more than they can afford to neglect or ignore the just complaint of a customer. Many firms now have security schemes, pension plans, benefit associations and other similar devices to protect workers during periods of idleness and old age. These are often combined with arrangements for avoiding unwarranted dismissals, unfair labour conditions, low wages and other grievances.[1]

A proper procedure for dealing with grievances is a necessity in any large industrial organization. The most usual causes of dissatisfaction are wages, supervision, loss of seniority, discharges or lay-offs and safety or health considerations. Collective bargaining agreements are now negotiated between management and workers (through unions or other accredited agencies) for the purpose of establishing a sound and stable relationship between the parties concerned. In these agreements the grievance procedure is usually specified in detail,[2] as also are the powers and privileges of the union or other bargaining agent.

Various systems of employee representation on *works councils* and on other committees have been devised and are in successful operation, enabling representatives of management and men to get together for the purpose of framing shop rules and settling grievances. The powers of these councils vary in different factories, but experience with them has indicated that much friction will be avoided when the necessity of taking unpopular action is

[1]See "The Scott McHale Plans," *Canadian Machinery*, August, 1939. "Pioneering in Security for Employees," *Manufacturing and Industrial Engineering*, May, 1937. Other schemes in *Manufacturing and Industrial Engineering*, October, 1937; November and December, 1938; January and September, 1939.

[2]*Management at the Bargaining Table*, Hill and Hook (McGraw-Hill), 1945, also Yoder (op. cit.) Chapters 21 and 22.

shown to the representatives of the workers, and the details discussed with them. Co-operation is thus substituted for antagonism.

Examples of this are the Procter and Gamble Employees Conference Committee, the Industrial Council of the Massey-Harris Corporation, plans of Employee Representation Bell Telephone Co. and Hydro Electric Power Commission of Ontario, and the Co-operative Committee systems of the Consolidated Mining and Smelting Company of Canada.[1] The last has the following sub-committees and representatives—

1. An Employment Committee (5 members).
2. Welfare and Relief Committee (5 members).
3. Election Committee (5 members).
4. Representative to Community Chest.
5. Medical Committee (9 members).
6. Fuel Committee.
7. Cost of Living Committee.
8. Picnic Committee.

A further example of co-operation in the textile industry is described by Nyman[2] where a "bi-partisan research committee of mill and union executives and a bi-partisan joint research staff under the direction of the committee and the supervision of a non-partisan technician" were organized to determine how much additional work could rightly be assigned to the workers, so that reductions in cost which were imperative, might be made without serious labour troubles.

In Australia,[3] failure to reach a voluntary agreement in a dispute, leads to compulsory arbitration. The award of the Court is binding on both sides and penalties are fixed for violation of the award. It is stated that this procedure is not entirely satisfactory and that the machinery of the Act "renders it imperative in practice that employers and employees should organize. The appearance of these rival organizations in Court as antagonists undoubtedly widens the breach between the parties. Industrial peace is expected to emerge as the result of a fight."

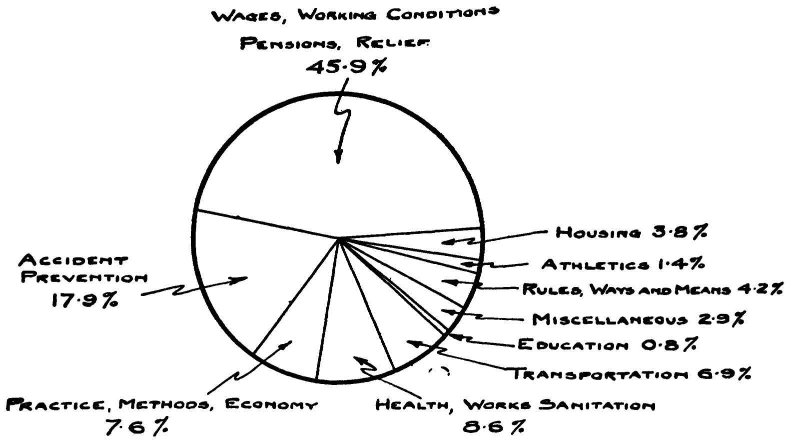
[1]Described in *Manufacturing and Industrial Engineering*, April and May, 1936.

[2]"Labour-Management Co-operation in Methods Development," *Mechanical Engineering*, February, 1935.

[3]"Industrial Relations in Australia," *Mechanical Engineering*, February, 1939.

Suggestion Systems.[1]

When any worker becomes expert at one particular job, it is almost inevitable that he will have some ideas regarding its improvement. Some firms have started suggestion schemes to enable them to benefit by improvements where it was possible



(*Courtesy of Bethlehem Steel Corporation*)

Fig. XVI.2. Analysis of Employees' Suggestions, 1918–1936

to apply them. Most of these systems have failed to produce the desired result for one or all of three reasons—

1. The reward was too small or too remote.
2. The workers were not satisfied as to the sincerity of the firm. They considered that their suggestions would be pigeonholed, and later adopted as the manager's or the foreman's ideas.
3. The fertility and resourcefulness of the employees were exhausted after two or three years, and the scheme petered out.

Apart from the third factor, which varies with the type of work done, the success of such schemes depends on the method of passing on and rewarding the suggestions. It is advisable in all cases, that representatives from the shop should be members of the committee that handles the suggestions. The method of payment may be on the basis of prizes offered periodically, or on the probable value of the suggestion. In some cases, a combination of the two systems is used, ordinary suggestions being rewarded by prizes and outstanding ones on the basis of value.

[1]The Suggestion System of the Eastman Kodak Co., is described in detail by Virgil M. Palmer (*Mechanical Engineering*, December, 1934, p. 731). The annual savings are stated to be $31,175 or $7.80 for every $1.00 paid in awards.

Dickinson[1] divides the objectives of a suggestion system into two classes, namely, (1) the technical worth of the suggestions which are independent of the suggesters, (2) the morale value which is peculiar to suggestions made by employees. The latter stimulates the interest and ingenuity of the men, indicates probable candidates for advancement and provides for the better ventilation of criticisms and grievances.

This paper includes statistics from eleven plants, of which five are large, five medium and one small. The number of suggestions per 1,000 employees ranges from 15–20 (life insurance) to 5,000–6,000 (small machinery manufacturer). The average payment for suggestions varied from $2 to $15.81, the highest award being $1,000. For suggestions which are of considerable value, a common basis of award appears to be 10 per cent of the saving produced by the suggestion during the first year of its use. The difficulty in such cases is to estimate the amount of the saving. In some instances, substantial prizes are offered which bear no relation to the economic value of the suggestions received. Regula, in the discussion on this paper, indicates the following general principles that are necessary for success when starting a suggestion system—

1. The plan must be "sold" by the management, as the foremen are generally apathetic or antagonistic.
2. There must be a clear and detailed statement of the plan.
3. The eligibility of the various classes (e.g. foremen) must be definitely stated.
4. The scale of awards must be definite and adequate.
5. Prompt action should be taken after receipt of suggestions.
6. In case of rejection, reasons should be given.
7. The interests of the suggester should be safeguarded—if preferred, the name of the individual should be withheld.
8. For some types of suggestion, non-financial incentives are preferable.
9. Constant, well-planned publicity is necessary for success.

The value of suggestion systems in wartime is illustrated by a statement of the Department of Munitions and Supply, Ottawa, to the effect that in one year $4,500,000 was saved in the cost of the war by suggestions contributed by the men and women workers of Canada. The following table gives an analysis

[1] "Suggestion Systems," *Mechanical Engineering*, November, 1934, also discussion in *Mechanical Engineering*, February, 1935, and May, 1935.

THE McKINNON INDUSTRIES, LIMITED, SUMMARY
EMPLOYEE SUGGESTION PLAN

	Total 13 Months May 1942 to May 1943 Inclusive	June	July	Aug.	Sept.	Oct.	Nov.	Total 19 Months Ended Nov. 30 1943
Under Consideration End of Previous Month	—	17	15	14	16	24	26	—
Submitted This Month by Eligible Employees	1,670	118	98	89	102	114	172	2,363
Accepted	264	22	23	13	16	26	37	401
Rejected	1,389	98	76	74	78	86	136	1,937
Under Consideration End of This Month	17	15	14	16	24	26	25	25
Percentage Accepted	16.0	18.3	23.2	14.9	17.0	23.2	21.4	17.2
Number Paid	252	18	19	18	15	27	32	381
Total Amount Paid	9,512.98	671.14	862.69	540.32	903.49	844.75	836.85	14,172.22
Highest Individual Award	750.10	221.76	223.54	72.89	520.45	285.00	406.00	750.10
Average Award	37.75	37.29	45.40	30.02	60.23	31.29	26.15	37.20
Net Annual Dollar Savings[1]	129,891.24	3,423.01	4,050.43	2,130.51	7,433.08	5,671.13	2,512.20	155,111.60
Annual Man Hour Savings[1]	45,270.0	4,661.0	2,384.0	3,497.3	2,359.0	3,714.9	[2]96.0	61,982.2

[1]These savings do not include any indefinite amounts representing awards on which savings are indeterminate.
[2]No explanation available for this comparatively small saving.

of suggestions received and action taken in 1942–3 by McKinnon Industries Limited, St. Catharines, Ontario.

Education and Apprenticeship.

The system of apprenticeship, whereby the learner was taught his trade by a master of the craft, was an integral part of the medieval trade gild. The conditions were stringent and no man was allowed to practise these trades without undergoing this novitiate. Admission to the engineering trade or profession via the apprenticeship route survived dissolution of the trade gilds by many years, being still prevalent in the early 1890's, but later, the increasing specialization of labour caused this system to fall into disuse. At that time there were two classes of apprentices, namely, the premium apprentice, who paid for the privilege of being taught, and the ordinary apprentice, who paid no entrance fee. The former type still exists in some professions, but it is practically extinct in the engineering world.

The application of scientific management and the increasing use of employment departments now give little opportunity for a young man to get the all-round training that was regarded as a necessity by the engineers of past generations. A man can no longer get experience in one class of work in one shop, and then transfer to another for different experience. His scope tends to become more and more limited as jobs are analysed and standardized, and as production becomes more, and still more, the criterion of human efficiency. Employees are judged by what they *do*, not by what they *can* do.[1]

These conditions have created a gap between the executive and the productive sections of industry which is becoming increasingly difficult to bridge, because younger men have not the opportunity of gaining the knowledge and experience that is necessary for leadership. Technical schools and universities for the purpose of giving theoretical instruction exist in large numbers, but the opportunity to apply this to the fullest extent is lacking. The rapid advance of the industrial arts has made a thorough grasp of their technical principles more necessary than ever before, but the opportunities available for the student to supplement his book knowledge by a variety of work in the shops are becoming steadily less. The technical progress of a nation and the productivity of its citizens depend on individual capacity and intelligent co-operation. This can only be realized to the full

[1]See "Lack of Production Capacity," Editorial *Engineering*, 13th March, 1936.

by a sound and well-balanced educational scheme. It applies to industries as well as to communities, and it is generally agreed that the economic progress of Germany has been due very largely to her system of technical education.[1] It is not the author's intention to describe the details of these systems, but he does wish to emphasize the importance of education to industry and the necessity of closer relationships between industrial firms and the various educational bodies or institutions.

Many mechanics now supplement their practical work by evening classes at technical or vocational schools, and in some cases, they also receive a preliminary day training at such schools. The considerations outlined above, however, have led a number of firms to revive the apprenticeship system, training their own men to fit them for foremanship or other executive positions. The apprenticeship training plan of Leyland Motors Ltd. (England) is shown diagrammatically in Fig. XVI.3. In this, *SI* stands for the first year of the senior engineering course and *AI* for the first year of the advanced engineering course. The apprenticeship system used by the Goodyear Tire & Rubber Company, Akron, Ohio, is typical of many others.[2] The best men are selected and they are allotted to mobile production and engineering squadrons; they do productive work in the machine shops and are required to take a course of study related to their work. The rate of pay varies according to a merit system which is based on the students' rating. Physical training in the gymnasium is compulsory, and social activities are encouraged by means of an apprentices' club.[3]

In most factories, the apprentice course lasts for three or four years, wages being paid both for hours of production and instruction. The technical classes may be provided by the firm[4] or, to divide the expenses, several firms in a particular locality may co-operate in a training scheme. Half-time schools (sandwich system) have been operated by the University of Cincinnati and other institutions. The students spend alternate weeks in the University and in the manufacturers' shops. The establishment of research laboratories by firms and combinations of

[1]For details of technical educational systems in the principal industrial countries, see *The Evolution of Industrial Organization*, by Shields, Chap. VII.

[2]"Apprenticeship in the Rubber Industry," by C. C. Slusser, *Trans. A.S.M.E.*, MAN. 51–15.

[3]Further details are given in a group of papers on Industrial Education in *Mechanical Engineering*, April, 1934.

[4]The "Ford" Trade, Training and Apprentice Schools are described in detail in *Canadian Machinery*, May, 1938.

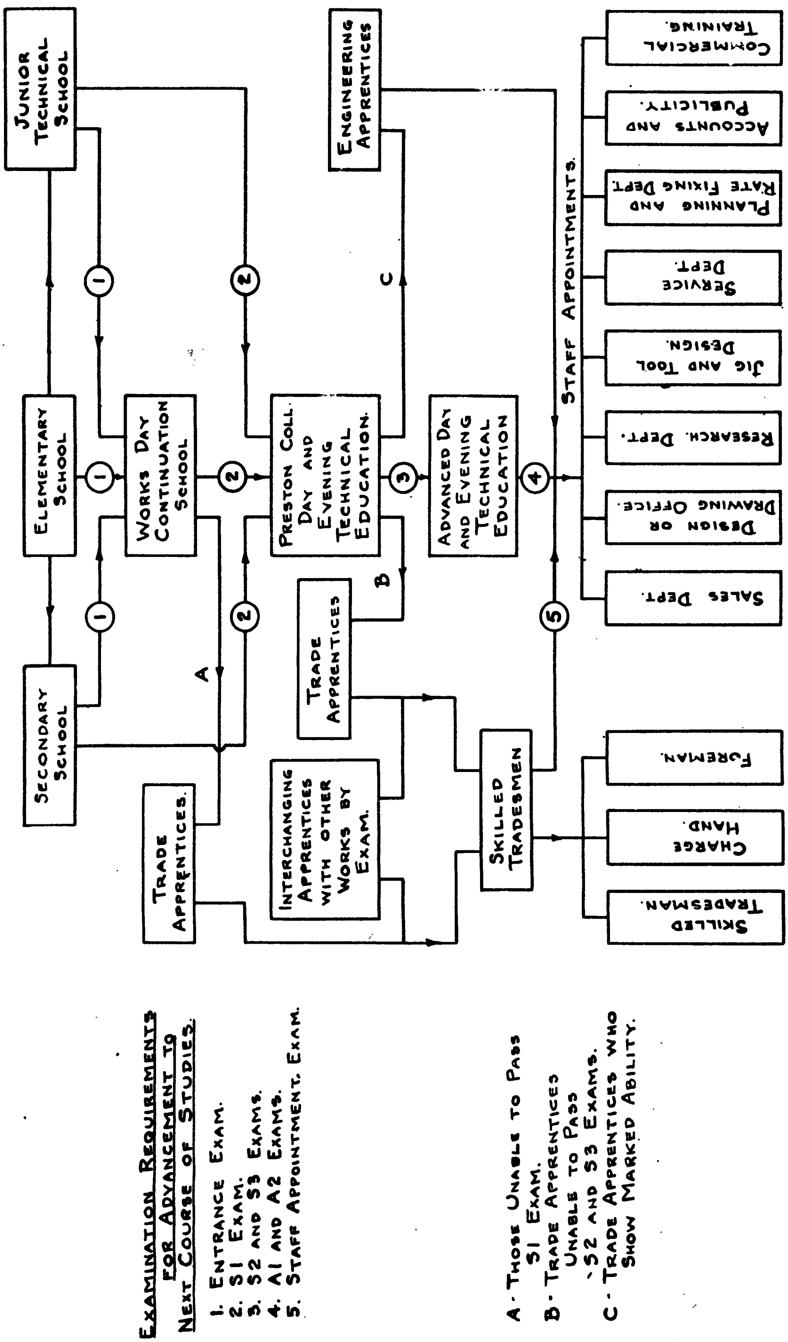


Fig. XVI.3. Training Plan for Leyland Apprentices

firms has provided another outlet. Students having the necessary qualifications and research ability have been able to investigate manufacturing difficulties, discover new products, and find new uses for old ones.

In 1933 the Secretary of Labour (U.S.A.) was authorized to set up an extensive programme to co-ordinate apprenticeship training throughout the country and in 1937 a law was enacted providing for the establishment of a National Apprenticeship Committee under the supervision of the Department of Labour. Minimum standards were set up regarding ages, working hours, instructional time and rates of pay. Many states have enacted similar laws and established supervisory Committees or Councils. An Apprenticeship Act was passed by the Ontario legislature in 1928 and by March 31, 1944, 5285 apprentices had been registered. A Dominion-Provincial Youth Training Programme was established in 1937 to assist youths in Ontario, who had suffered during the depression years, to obtain training in suitable vocations. The Vocational Training Co-ordination Act was amended in 1942 by the Dominion Government to stimulate apprenticeship training, and under an agreement between the Dominion and Provincial Governments (1944) the Province of Ontario pays 50 per cent of the total cost of training, including living allowance and transportation.[1]

The following general observations on the training of apprentices in Great Britain are taken from a paper by Fleming.[2]

1. There is a large amount of evidence to show that *systematic workshop training is a much more important factor than inherited manipulative skill in determining the efficiency of a craftsman.*

2. Consideration of the effects which the *introduction of modern tools and machinery* and *superior technical processes* have had on workshop practice, suggests the need during the training of trade apprentices for the *development of a greater degree of adaptability* and mechanical instinct than was perhaps necessary before these facilities existed.

3. Alteration in the *character of the work* required of craftsmen and of the responsibilities devolving on *foremen* renders it *impossible* for these men to play the same part in the *training of apprentices* as in the past.

4. It would seem desirable that in every firm, however small, it should be the duty of *some responsible officer* to undertake the work of

[1] "Activities and Responsibilities of the Ontario Department of Labour," Toronto, October, 1944.

[2] "Training of Apprentices for Craftsmanship," by A. P. M. Fleming, *Proc. I. Mech. E.*, 26th February, 1937.

See also "Education and Training for the Engineering Industry," *Jrl. I. Mech. E.*, April, 1939.

selecting the apprentices and of *organizing an appropriate scheme of practical training.* The form which this training might take, and the extent to which the German system of special apprentice workshops might be followed, will depend on the company's facilities and manufacturing requirements.

5. The apprentices should be encouraged to attend *part-time evening courses at technical schools,* and wherever possible these courses should be *supplemented by works' instruction* bearing more directly on the manual processes with which the boys are being called upon to deal.

6. *Increased attention* ought to be given to the provision of *facilities for physical training* and to stimulating, to the point of active participation, the *interest of apprentices* in subjects of a *cultural nature.*

7. The question as to whether the conventional period of training, which *in this country ends at* 21, should be changed to *a specific number of years as in the German system,* irrespective of the age of starting is a debatable one. The author is of the opinion that while a satisfactory knowledge of the technique of workshop processes can possibly be acquired in a highly organized four-year course, *the youth of* 18 *years of age is not sufficiently ripe* in general workshop experience *to undertake the full responsibilities of craftsmanship.* On the other hand, if for some reason *the starting age is later, being deferred* to, say, 17 or 18 years or more because of previous employment in "blind alley" occupation, *this shorter intensive period of training* should be sufficient.

8. The provision of adequate facilities for the *promotion* of superior trade apprentices is *an essential requirement* for a healthy industrial organization, but in the organization with which the author is associated it is not yet clear how best to maintain the appeal of craftsmanship as a life work and ensure adequate retention in the shops of the highest grade workers.

The education of foremen is also receiving considerable attention. The methods used generally include lectures and conferences or discussions in foremen's clubs. The latter develop self expression and reasoning powers and also tend to familiarize men who are engaged in specialized work with problems that are experienced by those in different branches of the industry. Some subjects, such as personnel relations, shop conditions, wage rates, job analysis, etc., are common to most foremen. The author has lectured to a number of these clubs, and has found the foremen very keen, critical, and anxious to learn.

Foremanship training was introduced by the Globe Wernicke Co., Cincinnati, in the early 1920's for the instruction and improvement of foremen and is now an important part of many other organizations.

There are three methods of approach to foremanship training programmes through information, instruction and conference. A file is prepared giving detailed information about each man, and

conference meetings are held featuring co-operative or instructional talks by the management. A Foreman's Club meets twice a month, at which each member is given an opportunity of instructing others of the group and giving demonstrations wherever possible. The conference method is used to pool the experience of a group in the solution of a problem and the discussions help the foremen to express themselves clearly. It is claimed that the results achieved have more than paid for the time and money spent on this scheme.

Safety.

The question of safety in industrial work may be considered under three heads, namely, the prevention of accidents, fire, and sickness. Accidents are responsible not only for the loss of production due to disablement of the worker, but also to the dislocation of the organization, increased overhead costs, and more labour turnover.

The humanistic aspect of this matter was well expressed nearly a century ago by Engel Dollfus who, in 1861, made the following declaration to the general meeting of the Industrial Association of Mulhouse—

> The manufacturer owes his workers something more than wages. It is his duty to consider their moral and physical well-being, and this obligation, which is a purely moral one and cannot be replaced by the payment of any kind of remuneration, must take precedence over his private interests. It is mainly to his feelings that he must look for guidance as to his conduct, for however perfect the legislation may be, however carefully responsibility may be defined, however low the accident insurance premiums and however liberal the text of the regulations, industrial progress will still continue to claim a certain number of victims who must pay with the loss of life or limb for a moment of inexperience, imprudence or forgetfulness.
>
> Nothing can be more dangerous or more regrettable than the type of fatalism which looks upon the industrial accident figures as a more or less immutable tribute which is required of us by fate or as an inevitable consequence of industrial work.

Causes of accidents vary in different industries, but the report of the Workmen's Compensation Board on Causes of Industrial Accidents in Canada (1939) indicates the risks of operating power equipment, in spite of the fact that such machinery is usually protected by suitable guards. It also shows that greater care should be exercised by workers. The number of accidents in each section is as follows—

Power equipment, including engines, shafting, abrasive wheels, saws, shapers, presses, etc.	10,479
Hoisting apparatus, including elevators	1,051
Dangerous substances (hot metals, steam, acids, electric current, etc.)	2,245
Stepping on or striking against objects	2,771
Falling objects	2,856
Falls of persons (including 3,720 on the level)	7,362
Handling of objects	11,759
Hand tools	4,996
Motor vehicles, wagons, trucks, trains, etc.	4,269
Flying fragments	3,485
All others	999
Total	52,272

Between 1914 and 1939 there were 1,373,677 claims for compensation and medical aid under the Province of Ontario Workmen's Compensation Act, at an average cost to industry of $98.22 per case.[1] During 1943 there were 121,237 accidents paid for, including 343 deaths and 1692 permanent disability cases. The indirect cost, due to lost production and other similar factors, is estimated to be about four times this amount. Among the principal causes of accidents are—

Physical causes—

1. Unguarded or badly guarded machinery.
2. Congested areas and badly piled materials.
3. Defective tools or equipment.
4. Unsafe buildings with dangerous floors, staircases, exits, etc.
5. Bad working conditions—ventilation, lighting, etc.
6. Improper planning or machinery layout.
7. Unsuitable dress, absence of goggles, gloves or head shields.

Supervisory causes—

(*a*) Faulty or incomplete instructions.
(*b*) Inexperience or poor judgment of the employee.
(*c*) Poor discipline resulting in interference or horseplay.
(*d*) Inattention or distraction of attention.
(*e*) Unsafe practices or undue haste.
(*f*) Mental unfitness, fatigue or boredom.
(*g*) Physical unfitness for the job.

[1]See "Safety in Industry," by R. B. Morley, General Manager, Industrial Accident Prevention Association of Ontario (*Engineering Journal*, November, 1938, pp. 499–501.)

An analysis, made by an individual company, showed that out of 1,642 disabling accidents 7 per cent were preventable by suitable safeguards supplied by the firm, 27 per cent were due to trade risk, and no less than 66 per cent could have been prevented by care on the part of the worker. In engineering as in other work, "familiarity breeds contempt," and the worker fails to recognize risks to which he has become accustomed by long use. Safety workers appreciate this fact, and various national and industrial "safety first" movements have been started to educate the workers in this respect.

The Goodyear Tire and Rubber Company of Canada uses the following devices to secure the interest and co-operation of employees—

(1) Bulletin Boards to attract attention.

(2) Employees are encouraged to furnish safety slogans, which are published over their names.

(3) Cash awards for safety suggestions.

(4) Every injury, however slight, must be treated in the plant hospital.

(5) Periodic questionnaire on the subject of hazards.

(6) Departmental safety records are posted periodically.

(7) Safety competitions.

(8) Special recognition of accident-free records.

Printed safety codes with appropriate illustrations are given to each employee by the Bell Telephone Company.

Comparisons are difficult to make because of the fact that accidents are reported more generally than they were years ago, but a paper by Alford[1] gives the accident experience of the Manville factory. During the first six months of 1929 the cost of accidents was $14,170 or 1.33 per cent of the total payroll. A safety movement was undertaken, and after this the cost of accidents for the first six months of 1930, was reduced to $4,100 or 0.73 per cent of the payroll.[2]

Chaney indicates that inexperience plays a large part in accidents, as the rate for employees with less than six months' service was 37.1 per million hours' exposure, falling to 14.1 after five years' service and 2.8 after fifteen years.

"Accident proneness"[3] is also a contributory factor in some

[1]*Mechanical Engineering*, December, 1930 (p. 1049).

[2]See also "Value of the Safety Movement in the Industries," by Podnossoff, *Trans. A.S.M.E.* (1931), MAN. 53–6.

[3]"The Personal Factor in Accidents", Industrial Health Research Board (Great Britain) H. M. Stationery Office.

instances. Various co-ordination tests have been devised to indicate this factor but, in general, the use of accident records is more applicable. If these records are kept in card form for each employee, they will show that anyone who is accident prone is liable to suffer more than the average number of slight mishaps.

Messrs. Procter & Gamble (soap manufacturers) estimate that one-third of the lost time for accidents is due to men employed less than two weeks, and the General Electric Company states that 50 per cent of their accidents occur to employees having less than six months' service with the company. Statistics also tend to show that men have a higher accident rate than women engaged on the same work, that single men tend to have a higher rate than married men, and that unskilled men are more prone to accidents than are skilled men.

Opinions vary as to the contribution of increased speed of production to the accident rate. Dr. Vernon, in a memorandum to the Health of Munition Workers Committee (England), considered that speed of production was the principal factor in causing accidents, while the Committee on Engineering Safety and Production of the American Engineering Council says that "the results lead unmistakably . . . . . to the implication that there exists a high degree of correlation between industrial safety and industrial productivity, and that the combination of low accident rates and high production rates is possible of attainment by any industrial group."

Preventive devices and education will reduce the number of accidents, but those that do occur must be promptly and effectively handled. Many deaths are due to blood poisoning, caused by neglect of apparently trivial accidents. Suitable first-aid appliances, together with men accustomed to their use, must be a part of the equipment in every shop. In one factory it was also necessary to sterilize the cutting lubricant, so that dirt and germs were eliminated.[1]

In Ontario, safety education and organization is provided by the Industrial Accident Prevention Associations, which also provide inspection services and safety literature, hold meetings and conventions and keep records of accident rates. The effectiveness of safety education and mechanical safeguards is indicated by the experience of many Canadian firms, some of whom have accident-free records of from one to three million man-hours.

[1]*Machine Shop Management*, by Van Deventer, p. 364.

Graniss[1] suggests the following procedure for investigating and reporting accidents—

1. Describe details of accident.
2. Note the object, tool, machine, toxic substance or other detail most closely associated with the injury.
3. Determine the part of (2) which may have been involved.
4. Was the object or part unguarded, defective or otherwise unsafe?
5. Accident type, for instance did the person fall, or was he struck by some object?
6. Indicate the unsafe act (if any) on the part of the person injured.
7. State whether there were any personal defects of the employee that might have contributed to the accident.

The protection of workers and equipment from fire, and the provision of adequate ventilation, lighting, and sanitary appliances have already been considered (Chapter XI), but in the case of fire it is well to remember that the best apparatus is valueless unless there is a proper organization for using it. Factories frequently have their own fire brigades and salvage men, but also, there should be some men on each floor who will take charge if a fire occurs, and whose duty it is to prevent panic and unnecessary congestion in passages and doorways. A periodic inspection should be made of all fire fighting appliances to see that they are kept in proper order and ready for use.

Welfare Work.

The transfer of ownership, following the Industrial Revolution (Chapter I), resulted in the workman being regarded as a kind of chattel, from whom as much work as possible was to be extracted with a minimum of expenditure. The advent of scientific management and the specialization of work tended to emphasize the mechanization of industry, so that in many places far more care and attention was given to the machinery and even to the animals than was devoted to the human element upon which successful operation depends. It is true that the pioneers in scientific management pointed out the desirability of getting suitable labour for each job, but this was an industrial rather than a social or moral feature, and its wider implications were generally ignored.

[1] "Accident Investigation and Cause Finding," *Mechanical Engineering*, March, 1941.

Welfare work, however, is not new; it formed part of the regulations of the craft gilds. The apprentice was provided with food, clothing, and shelter; payments were made in cases of sickness, unemployment and old age, and donations were made from the common fund in the event of members suffering losses from theft or fire. In spite of the general factory conditions following the Industrial Revolution, one, at least, of the employers, Robert Owen of New Lanark, Scotland (about 1800), was alive to the importance of welfare work. He erected a model village, improved sanitary conditions, provided a library, schools, and facilities for recreation, and reduced the number of working hours from thirteen or fourteen to ten. His contemporaries considered this work to be extravagant and useless, but the business prospered in spite of or perhaps because of it. Several other enlightened employers followed this lead and the movement gradually gained strength, receiving a considerable impetus during World War I, as stated in Chapter I.

The definition of welfare work by the British Welfare Workers' Institute is, "that part of the management concerned with the organization of working conditions on such lines as will be acceptable to and provide for each individual worker, (1) physical comfort and well-being, (2) the full opportunity for the use of his work and abilities, (3) the means for the development of all his faculties. It aims at assisting the individual to fulfil his functions, both as a citizen and producer, in the interest of the community, as well as of the particular enterprise with which he is connected. It seeks to promote a better understanding between employer and employed, based on just dealing and mutual co-operation."

It is evident that, co-existent with improved facilities for production, there must be the best possible class of worker and the most comfortable working conditions both within and without the factory.

In addition to profit sharing plans, many large firms have pension and life insurance plans, disability and death benefits, vacations with pay, guaranteed hours and other privileges for the purpose of promoting, as far as possible, social security.

The organization of the welfare department depends largely on the motive for its adoption. If the idea is merely to improve production, it may be part of the service department and will be administered by the management. If it is developed largely on humanitarian grounds, a part of the direction, at least, should

be in the hands of the employees. Clubs, recreation facilities, and athletics should be handled by the workers, while in many cases the restaurant or mess is also controlled by them. A cheap supply of well-cooked food is important from the standpoint of physical well-being, and is being recognized as an essential part of welfare work. The meals supplied are less costly than those from an ordinary restaurant because there are no profits or overhead costs to be allowed for, and the building itself is frequently used also as a centre for social activities. In small communities, co-operative stores, where goods can be bought by work-people at cost price plus the cost of handling, are sometimes provided by the firm.

Most firms now provide for systematic medical inspection and supervision. The medical department may handle any or all of the following—

Physical examination of—

(*a*) New or prospective employees.
(*b*) Employees in hazardous occupations.
(*c*) Employees transferred to new jobs.
(*d*) Employees resuming their occupation after illness.

Accidents—

First aid service.

Health service—

(*a*) Home or hospital.
(*b*) Systematic examination of employees.
(*c*) Sanitary supervision of plant.
(*d*) Health education.

Dental service is also provided in some instances.

The National Industrial Conference Board (U.S.A.) has estimated the cost of this service as varying from $4.50 to $6.00 per worker per annum.[1] Their report also states that factories employing less than 500 workers should have a part-time physician; those having between 500 and 2,000 employees may have a part- or full-time physician, and those with over 2,000 should certainly have a full-time physician. The cost of doctors, nurses, dispensaries, etc., is not entirely an additional charge on industry, as it is offset by reduced compensation, lost time and labour turnover. Home visitation enables causes of absence to be checked, but this should be done with discretion. The spread

[1]The cost at Trail, B.C., is stated to be $3.40 per month for all health service for employees and their dependants. Of this 90 cents are contributed by the Company. *Manufacturing and Industrial Engineering*, April, 1936.

of communicable diseases is checked and occupational diseases may be prevented by efficient health instruction and service.

The cost to industry of absences due to illness was estimated by Roberts and Brown[1] at $60 per employee per year. It was also stated by them that while strikes in 1940 resulted in a loss of time of about two hours per worker per year, the lost time due to illness was four times this amount. Occupational diseases constitute less than 10 per cent of this problem. The medical consultant for General Motors stated that, during the first half of 1939, respiratory diseases accounted for 50 per cent of the absences due to illness, and digestive diseases (most of them preventable) for 15 per cent.[2] In July, 1939, this company expanded its group insurance plan to include hospitalization and surgical benefits, and in that year the total benefits paid to their employees under the health maintenance programme was slightly more than $4,000,000.[3]

Occupational diseases due to dust, fumes or toxic gases, are receiving increased attention, as these may cause respiratory troubles or poisoning (as in the case of lead).[4] These may be avoided by the use of proper exhaust equipment to remove the dust or gases before they reach the worker, or by suitable respirators or masks. A survey of the industrial field from the health standpoint is given in a paper by Sayers and Dallaville[5] from which the following extract is taken—

> Dublin has evaluated the effect of the industrial environment on the well being of a large number of workers in a mortality study among more than three million white, male wage earners. The study covered a three-year period from 1922 to 1924, inclusive, and is compared with a similar study made over a similar period from 1911 to 1913. The groups studied constituted a fairly representative social and economic class and were considered as an urban earning population. Dublin has shown by an analysis of the data obtained, that adult males engaged in industrial pursuits had a higher mortality and a shorter longevity than those in other types of work such as professional, clerical, etc. In the more recent study, it was further shown that the mortality rates for the industrial workers were more than double the rates for the non-hazardous occupations. In terms of life expectancy, the picture presented was impressive. The industrial worker at the age of 20 had an expectancy of 42 years as compared with the normal of 49 years. In other words, the life of the industrial worker in 1924 was

[1] *Advanced Management*, April–June, 1941.
[2] *Mechanical Engineering*, April, 1940.
[3] *Engineering Bulletin*, Purdue University, November, 1940, pp. 18–19.
[4] For details see "Dangerous Dust and Fumes Cause of Industrial Diseases," by Dr. F. M. R. Bulmer, *Canadian Machinery and Manufacturing News*, May, 1937.
[5] *Mechanical Engineering*, April, 1935, p. 230.

shortened by approximately seven years, while the data for 1911 to 1913 showed the decrease in longevity to be even greater. Considering the characteristics of the groups studied, Dublin was led to the conclusion that in the industrial environment, exposure to abnormal conditions such as toxic dusts, vapours, fumes and gases, radiant heat, etc., explains the difference in longevity between industrial and non-industrial workers. Since, furthermore, there are some 900 separate occupations with exposure to occupational-disease hazards, the magnitude of the preventive problem should merit considerable attention.

The authors recommend a plant survey and an occupational analysis, the latter being intended to show the severity of the exposure of various occupational groups and to correlate the findings with medical examinations.

Locker and rest rooms should be provided and, in some industries, it is desirable to provide facilities for bathing or changing apparel before employees leave the works. It was found by Dr. Gier that greatly increased liability to respiratory diseases was incurred by workers whose clothes were saturated with perspiration. Pride in personal appearance also frequently inculcates desirable habits and improves conditions of the shops.

The British Factory Acts have effected considerable improvements in conditions of work and in the supervision of dangerous trades, and have laid down regulations regarding cleanliness, overcrowding, safety devices, and other aspects of industrial welfare.

The use of recorded music as an antidote to boredom has already been referred to in Chapter I. This is said to act as a mental tonic, improve health and happiness, reduce conversation, relieve mental strain and cut down absenteeism. It must, however, be of a suitable kind. It is stated that—

(1) Hymns slow down production.
(2) "Hand-clapping" tunes take the workers' hands off their machines.
(3) Vocal refrains produce a dreamy attitude.
(4) "Hot swing" puts people off their stride.

The British Broadcasting Corporation investigated this matter during World War II and arrived at the following conclusions[1]—

(*a*) The music should be familiar to the ordinary worker.
(*b*) The melody should be clear and well defined.
(*c*) The tone level or volume should be constant.
(*d*) Extremes of fastness or slow time should be avoided.

[1] "Music while you work," by Wynford Reynolds (B.B.C., 1942).

(*e*) Music is best suited to repetitive or monotonous work (especially with female labour).

(*f*) Loud speakers should be small and well placed about the factory.

(*g*) For a normal working day, two and a half hours of musical programmes should be sufficient.

It is also claimed that rest periods of five to twenty minutes in the forenoon, and five to fifteen minutes in the afternoon, have the following advantages—

1. Improvement of accuracy in handling equipment and materials.
2. Elimination of surreptitious eating during operating periods.
3. Reduction of lost time due to unauthorized rest periods.
4. Improvement in morale and goodwill.
5. Reduction in proneness to accident.

Some firms also reported an increase in production, others reported no change.[1]

While every effort should be made to obtain better living conditions for the workers, undue paternalism by interference with the home life of the employees should be avoided.

[1]*Manufacturing and Industrial Engineering*, November, 1939.

CHAPTER XVII

WASTE

One of the principal objectives of good management is the prevention of waste. This includes all expenditure of material or time that does not yield its full equivalent product. It may be incurred deliberately or through mismanagement, or it may be the result of causes that no industry can control. But, however it arises, it is a permanent loss of industrial and national resources, and so impoverishes the average individual throughout the entire community.

The following example of the incidence of waste is extracted from an article in "*The Times*" *Engineering Supplement.*

Suppose, for instance, that the intermediate product is a house in which a worker has to live, and that for whatever reason three times as long as necessary has been spent on building; a considerable understatement of the waste in much recent building, but sufficiently near to illustrate the principle. At once the rent of that house, so far as it depends on the cost of the building, becomes three times as large as it need have been; that is to say, the tenant has to devote three times as much of his resources to paying his rent as he need otherwise have spent, or if this rent is not paid, the owner has to lose the use of a corresponding amount of his own resources and have correspondingly less available for other industrial purposes. The slackness or overpayment of the builder is a single transaction, limited to a few weeks or a few months; but the resulting waste extends throughout the whole of the generations that inhabit the house. If, again, the intermediate product is a work of public utility—say a road—rates or taxes will similarly—and with similar results—have to continue inflated until the cost of the road with interest has been paid off. The same is true of money spent in unemployment allowances to men for whom productive work could be found but is not, or who are paid more than the value of what they produce.

Rates and taxes may reduce the substance of industry, but whether they constitute a communal waste depends upon whether better value is obtained by local or governmental expenditure, or by the use of the money by industry for productive purposes. In any case, industry suffers from excessive taxation, whether direct or indirect, by reason of the fact that possible capital is withdrawn from it.

Every kind of industrial waste is paid for eventually by the consumer, who may take one of three courses—

(*a*) He may increase the price of what he himself produces.

(*b*) He may reduce the amount of his purchases.

(*c*) He may change his source of supply to another firm or to another country.

All these ultimately result in increased unemployment, and the community, as a whole, suffers by reduced income.

Management, therefore, must bear the responsibility for seeing that its organization is of an efficient nature and directed towards the elimination of unnecessary waste.

Waste is due to a variety of causes, including—

1. Transportation wastes both of time and material, due to unnecessarily long hauls, improper or excessive handling and deterioration of product.

2. Wastes due to improper, inadequate or antiquated equipment.

3. Wastes due to processes. Engelbach[1] pointed out that in an automobile press shop the waste was 35–40 per cent, only 3 to 5 per cent being due to faulty work. This resulted in an annual loss of over $500,000. He also indicated that 4.29 tons of material were required to produce one ton of automobile. In the foundry 10.6 tons, and in the drop forging shop 14.6 tons of material were required to produce one ton of product.

4. Waste due to character of product, which may be insufficiently standardized or inconvenient in form or design, so that an unnecessary amount of work is required to produce it.

5. Waste of stores or accessories. The Westinghouse Company indicated the importance of these items in the factory expenditures as follows—

Lubricants	$22,000	per month
Gas	13,000	"
Water	10,000	"
Stationery, etc.	10,000	"
Waste and rags	1,800	"
Paper towels	1,400	"
Paint brushes	1,100	"

It was stated that if every employee could save 5 cents per day, the annual saving would be $300,000 for that company alone.

A rivet sorting machine, which enables rivets accidentally dropped on the floor to be reclaimed, saves $12,500 per annum for an aircraft manufacturing plant in the U.S.A.

[1]Presidential address, Institution of Automobile Engineers, 1933.

6. Waste of power due to improper maintenance and carelessness.

The means of avoiding most of these sources of waste have been described in the foregoing pages, but campaigns for the reduction of waste have been carried on successfully in many factories.

Two of these are described in the transactions of the American Society of Mechanical Engineers (Sept.–Dec. 1929), one being a national and the other a factory campaign.

The Committee on the Elimination of Waste in Industry, appointed by the American Engineering Council, classified waste in industry as due to—

1. Low production, caused by faulty management of materials, plant, equipment, and men.
2. Interrupted production, caused by idle men, materials, plant, or equipment.
3. Restricted production, intentionally caused by owners, management, or labour.
4. Lost production caused by ill-health, physical defects, and industrial accidents.

The Oakland Motor Car Company[1] organized a war on waste in a factory of 10,000 employees. The cost was $16,167, and the anticipated savings $542,000. The Newport News Drydock & Shipbuilding Company saved $242,000 in the same way.

The Detroit Edison Company[2] uses an abandoned power house as a centre to which all salvaged materials and equipment are sent. A monthly salvage report is compiled. Old and infirm employees, who are no longer able to carry on their regular duties are kept busy on this work so that the salvage is human as well as material. Scrap is disposed of directly from the point of removal and items which are to be retained for sale or further use are transferred to the salvage building. All sales are under the supervision of the purchasing department. During the years 1935-38 inclusive, the volume of salvage business of the division has averaged close to a million dollars.

The Caterpillar Tractor Company of Peoria, Illinois, in 1941 had a working force of 50 men in the Reclamation Department.[3] Scrapped tools made of high speed steels are sorted out by spark testing and boxed for shipment. Scrap lead is made into lead hammers, files recut, plug gauges ground to smaller sizes, special

[1] *Trans. A.S.M.E.* Paper No. Man. 51–14.
[2] "Salvage in a Utility Company," *Mechanical Engineering*, August, 1939, p. 617.
[3] *Industrial Power*, November, 1941.

wrenches repaired, jigs and fixtures are dismantled and reclaimed in part. Records are kept of all reclaimed material and careful inspections are made. In 1940 nearly one and a half millions of pieces were made from scrap crop ends and slugs.

The salvage campaign makes use of a definite organization to reach every section of the business and works through the medium of posters, bulletins, speeches, and exhibits. Adequate publicity and effective demonstration are both necessary for success, and a staff must be appointed to consider suggestions, classify them and award prizes. The Oakland Company received 3,558 suggestions during this campaign, which lasted for two weeks.

Auel[1] recommends a reclamation scheme in the form of a "clean up" inventory. All obsolete, unnecessary, or surplus tools or materials are cleared out of all departments periodically and sent back to the stores to be restored to condition, or disposed of. Care is then taken to see that these wastes do not recur. If waste is prevented, there is no need for salvaging.[2]

[1] *Trans. A.S.M.E.* Paper No. Man. 51-13.

[2] See also "Prevention of Waste and Reclamation of Materials," by J. Q. Salisbury, *Mechanical Engineering*, September, 1935, p. 563.

CHAPTER XVIII

SCIENTIFIC MANAGEMENT

Claims.

The principles of scientific management as introduced by Taylor and expanded or modified by his successors in this field have been outlined in the previous chapters, but it is advisable at this point to present them in summarized form, to consider briefly the results obtained from their application to industry, and the attitude of labour towards them.

These claims were the subject of an investigation made in 1915 for the United States Commission on Industrial Relations, and the report is given fully in a book by Hoxie on *Scientific Management and Labour.*

Briefly, the claims made for scientific management are—

1. Elimination of waste, improvement of productive methods, and just and scientific distribution of products.
2. Harmonious co-operation between employers and workers.
3. Substitution of exact knowledge for guesswork, and establishment of a code of laws binding on all parties.
4. Substitution of natural laws in place of arbitrary and capricious codes of discipline.
5. Adoption of specialization but mitigation of its evils.
6. Elimination of over-speeding and nervous and physical exhaustion of workers.
7. Selection of the best worker for the task.
8. Provision of vocational guidance and training for the workers.
9. Payment of each man according to his efficiency.
10. Elimination of systematic "soldiering" or limitation of output.
11. Promotion of friendly relationships between management and men and also between the members of various groups.
12. Increase of the skill and productivity of the workers.
13. Improvement of quality of product.
14. Shortening of the hours of labour and improvement of shop conditions.
15. Raising of wages.
16. Decreasing of unemployment.

17. Making trade unions and collective bargaining unnecessary as a means of protection to the workers.

18. Prevention of strikes and removal of causes of industrial unrest.

These, and other similar claims, have been investigated by the Commission, who found that in the systems *as applied* they were generally not realized, or at best, only partly attained. The following extract from their final conclusions indicates the general trend of the report—

> Two essential points stand forth. The first point is that scientific management, at its best and adequately applied, exemplifies one of the advanced stages of the industrial revolution which began with the invention and introduction of machinery. . . . Scientific management, at its best, has succeeded in creating an organic whole of the several departments of an institution, establishing a co-ordination of their functions which had previously been impossible, and, in this respect, it has conferred great benefits on industry. The social problem created by scientific management, however, does not lie in this field. It is in its direct and indirect effects upon labour that controversy has arisen, and it was in this field that the investigation was principally made. . . .
>
> The second point is that neither organized nor unorganized labour finds in scientific management any adequate protection to its standards of living, any progressive means for industrial education, or any opportunity for industrial democracy by which labour may create for itself a progressively efficient share in efficient management. And, therefore, as unorganized labour is totally unequipped to work for these human rights, it becomes doubly the duty of organized labour to work unceasingly and unswervingly for them, and, if necessary, to combat an industrial development which not only does not contain conditions favourable to their growth, but, in many respects, is hostile soil.[1]

Objections.

The objections of trade unions are given fully. Organized labour believes in "science in management," but its objections are directed solely against systems devised by the "scientific management" cult. It is considered by the men that scientific management is a cunningly devised speeding system which tends to displace all but the fastest workers, intensifies the modern tendency toward specialization, tends to eliminate skilled crafts and degrades skilled workers to the condition of the less skilled. They claim that it establishes a rigid system of wages regardless of the cost of living, tends to lengthen the hours of labour, and lessens the certainty and continuity of employment. It further puts into the hands of the employers a mass of information and

[1]See also "Problems of Scientific Management in Unionized Plants," *Mechanical Engineering*, March, 1938.

methods which can be used unscrupulously to the detriment of the workers.

It will be seen that the more important of these objections are directed against the method of applying the system rather than against its fundamental principles, and most of these objections were confirmed by the Commission.

Since 1915, many of these difficulties have been overcome by experience. William R. Leiserson, in a paper read before the Taylor Society[1], states that many of Labour's objections are due not to the particular nature of scientific management, but to the introduction of changes of any kind, and brings forward evidence to prove his point. An article by H. S. Person in the *Encyclopaedia Americana* states that strong opposition has been experienced from the labour unions in plants where improved industrial relations have been developed by scientific management. He indicates further that the arguments against this system were prompted by inadequate information, that they were not supported by the facts, and that in many cases, they were really arguments concerning administrative policy and were not more pertinent to scientific management than to any other form of management. Again, he says that since the First World War, the managers and engineers of these plants "have been in the van of those inspiring and directing the establishment of the most humane and co-operative and administrative policies, in accordance with the most far-sighted of industrial relationship."

For good or ill, there is no question that the application of scientific principles to management has effected a profound change in industrial operations and relationships, and it is probable that more good than harm has been done. However, whatever one's personal opinion may be on that point, the clock is unlikely to move back, and it is necessary to make the best and most humane use of the new tools that have been provided.

Peter Van Dresser[2] comments on the situation in the following terms—

> Men now have a way to multiply their strength as individuals. The machine does not demand that men now organize their material world more thoroughly than it has even been organized before. On the contrary, the more nearly the machine approaches perfection the more it makes possible for us to reverse this trend without the sacrifice of civilization which such a reversal has always before entailed.

[1] See *Scientific Management Since Taylor*, by E. E. Hunt.
[2] *Harper's Monthly Magazine*, "Machines and Individuals".

Distribution.

The first of the claims tabulated at the beginning of this chapter included the scientific distribution of products. Scientific production has far outstripped distribution, and the latter is the problem that must be solved if the benefits derivable from mass production are to be realized. Foodstuffs have been destroyed in one country because there was no sale for them, while people in other countries, or in other sections of the same country were starving. Similar conditions exist in many industries. A paper by Mooney includes the following comments on this situation[1]—

> The manager has been too busy with the day's production details to bother with a broad look around, and meantime the medicine men of high-pressure selling have taken over his distribution problems. And our high-pressure selling of the past several years has been characterized not only by a great development in technique of "ballyhoo," but also by a lack of interest in the development of a philosophy or knowledge of the economics of distribution. . . .
>
> We have made a great fetish of saving pennies in direct production costs, but have been content meanwhile to waste dollars lavishly in distribution costs. The mechanisms of mass production have the excellence and finesse of the up-to-the-minute 12-cylinder motor car, but the designs and functionings of distribution schemes remind one of a 1914-model farm tractor.
>
> Perhaps we might borrow usefully the approach of the modern mining engineer, who insists on making extensive geological researches and provings, and on blocking out great masses of ore in his mining property before he recommends to capital the investment of huge sums in mills and smelters. The days of the "divining rod" in mining are long since past.
>
> Better still, the administrators of manufacturing industries might borrow some lessons from the mechanical and electrical engineers who design and operate electric power and light utilities. Here, generally, an excellent job has been done in relating the size of the plant and investment to the area or size of the market available for the service, in making such rates and classifications of rates as will result in the best load factors, and generally in establishing relationships that will provide the best return on investment under the market or service conditions that impose themselves on the electrical utility[2].

Conclusion.

The importance of management in the industrial field, and the number and diversity of its functions have been indicated in

[1] "Current Problems of Industrial Management," *Mechanical Engineering*, July, 1932.

[2] See "The Technique of Marketing Research," by G. W. Kelsey, *Mechanical Engineering*, December, 1934, p. 723.

the preceding chapters. It occupies the same position in industry as does the general staff in an army, and as the latter would fail to operate with unity and precision without the staff, so the former would be as a body without a head if efficient management were lacking.

For arranging equipment and handling materials, precise knowledge and methodical procedure are necessary; for managing men these must be supplemented by tact, discretion, and kindness. The science of management is young, as compared with many of the other arts and sciences. Its potentialities as yet are scarcely realized. Wallace Clark[1] indicates the desired objective in the following paragraph—

> The engineer sees executives imparting to others the knowledge which they formerly kept entirely to themselves, and whole groups of industries overcoming their suspicions and exchanging information for mutual benefit. He sees commercial agreements being made which disregard boundaries and forget the fears and hatreds of the past. He hears the shouting of warriors and idealists exhorting people to follow them to freedom and happiness, but as he goes on with his work, he watches the machine age and the new management breaking down barriers, healing old wounds, wiping out poverty, and giving men more freedom to develop themselves and to prepare the next generation to lift higher the torch of progress.

LIST OF BOOKS REFERRED TO IN TEXT

Author	Title	Publisher
ALLCUT & KING	Engineering Inspection	*Routledge*
ALLCUT & MILLER	Materials and Their Application to Engineering Design	*Griffin*
ANDERSON	Industrial Engineering and Factory Management	*Ronald Press*
AMERICAN SOCIETY OF MECHANICAL ENGINEERS	Transactions, "Mechanical Engineering" and "Journal of Applied Mechanics"	*A.S.M.E.*
BARNES	Industrial Engineering and Management	*McGraw-Hill*
BARNES	Motion and Time Study	*McGraw-Hill*
BASSETT & HEYWOOD	Production Engineering and Cost Keeping	*McGraw-Hill*
BETHEL, ATWATER, SMITH & STACKMAN	Industrial Organization and Management	*McGraw-Hill*
BRISSENDEN & FRANKEL	Labour Turnover in Industry	*MacMillan*
CARROLL	Time Study for Cost Control	*McGraw-Hill*
CHURCH	Manufacturing Costs and Accounts	*McGraw-Hill*
CLARK	The Gantt Chart	*Ronald Press*
DICKINSON	Compensating Industrial Effort	*Ronald Press*
DIEDRICHS & ANDRAE	Experimental Engineering	*John Wiley*
DIEMER	Factory Organization and Administration	*McGraw-Hill*

[1] *Trans. A.S.M.E.* Paper No. MAN. 53–1.

LIST OF BOOKS REFERRED TO IN TEXT (*contd.*)

Author	Title	Publisher
DURANT	The Life of Greece	*Simon & Schuster*
DURANT	Caesar and Christ	*Simon & Schuster*
ELBOURNE	Factory Administration and Cost Accounts	*Longmans Green*
ELBOURNE	Fundamentals of Industrial Administration	*Macdonald & Evans*
GARDEN	Flexible Budgeting and Control	*Macdonald & Evans*
GILBRETH	Motion Study	*Van Nostrand*
GUSHEE & BOFFEY	Scientific Purchasing	*McGraw-Hill*
HILL & HOOK	Management at the Bargaining Table	*McGraw-Hill*
HOXIE	Scientific Management and Labour	*Appleton*
HUNT	Scientific Management Since Taylor	*McGraw-Hill*
INST. OF MECHANICAL ENGINEERS	Proceedings and Journal	
JACKSON	Engineering's Part in the Development of Civilization	*A.S.M.E.*
JOHNSON, BOISE & PRATT	Job Evaluation	*John Wiley*
JONES	Administration of Industrial Enterprises	*Longmans Green*
KIMBALL & KIMBALL	Principles of Industrial Organization	*McGraw-Hill*
KOEPKE, C. A.	Plant Production Control	*John Wiley*
LAIDLAW & YOUNG	Engineering Law	*University of Toronto Press*
LANSBURGH & SPRIEGEL	Industrial Management	*John Wiley*
LINK	Employment Psychology	*MacMillan*
LOWRY, MAYNARD & STEGEMERTEN	Time and Motion Study	*McGraw-Hill*
MAGOUN	Problems in Human Engineering	*MacMillan*
MARSHALL	Graphical Methods	*McGraw-Hill*
MAYNARD & STEGEMERTEN	Operation Analysis	*McGraw-Hill*
MICHELON, L. C.	Industrial Inspection Methods	*Harper Bros.*
MOGENSON	Common Sense Applied to Time and Motion Study	*McGraw-Hill*
MOORE, HERBERT	Psychology for Business and Industry	*McGraw-Hill*
PITTS, M. W.	Materials Handling Equipment	*Pitman*
RICHARDSON	Industrial Relations in Great Britain	*International Labour Office*
RINDSFOOS	Purchasing	*McGraw-Hill*
RAUTENSTRAUCH	Industrial Surveys and Reports	*John Wiley*
SCOTT	Budgetary Control and Standard Costs	*Pitman*
SHEWHART	Economic Control of Quality	*Van Nostrand*
SHIELDS	Evolution of Industrial Organization	*Pitman*
SMYTH & MURPHY	Job Evaluation and Employee Rating	*McGraw-Hill*
SPICER	British Engineering Wages	*Arnold*
SCOTT, CLOTHIER, & MATTHEWSON	Personnel Management	*McGraw-Hill*
TAYLOR	Shop Management	*McGraw-Hill*
USHER	History of Mechanical Inventions	*McGraw-Hill*

LIST OF BOOKS REFERRED TO IN TEXT (*contd.*)

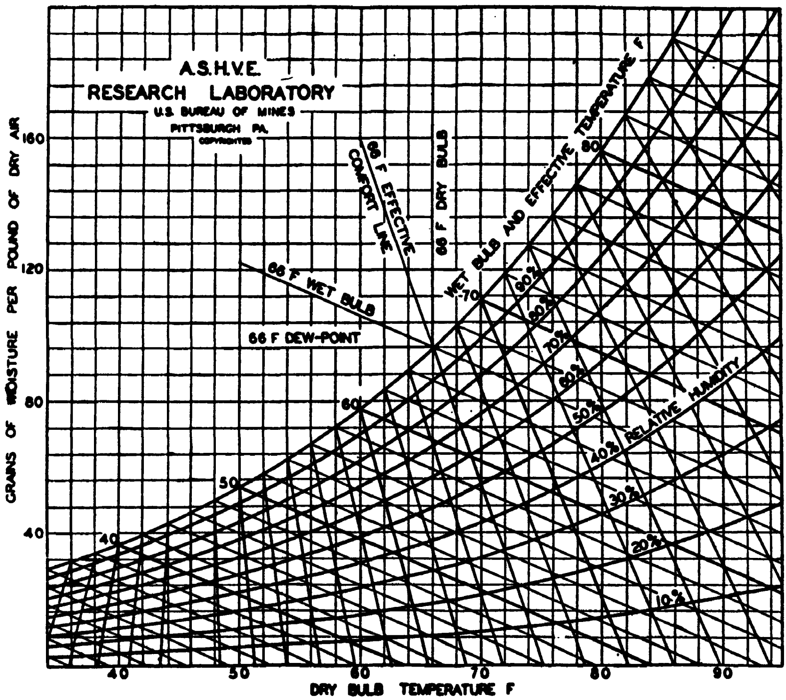
Author	Title	Publisher
VAN DEVENTER	Machine Shop Management	*McGraw-Hill*
VERNON	Principles of Heating and Ventilation	*Arnold*
VOWLES	The Quest for Power	*Chapman & Hall*
WALKER	Management Engineering	*McGraw-Hill*
WILLSMORE	Business Budgets and Budgetary Control	*Pitman*
YATES	Wages and Labour Conditions in British Engineering	*Macdonald and Evans*
YODER, DALE	Personnel Management and Industrial Relations	*Prentice-Hall*
YOUNGER & GESCHELIN	Work Routing, Scheduling, Dispatching	*Ronald Press*

APPENDIX I

THE PSYCHROMETRIC CHART

This chart is used by the American Society of Heating and Ventilating Engineers, and serves two purposes—

(*a*) For any given dry and wet bulb temperatures, the corresponding relative humidity and moisture content of the air can be obtained quickly and conveniently.



(*Courtesy of American Society of Heating and Ventilating Engineers*)

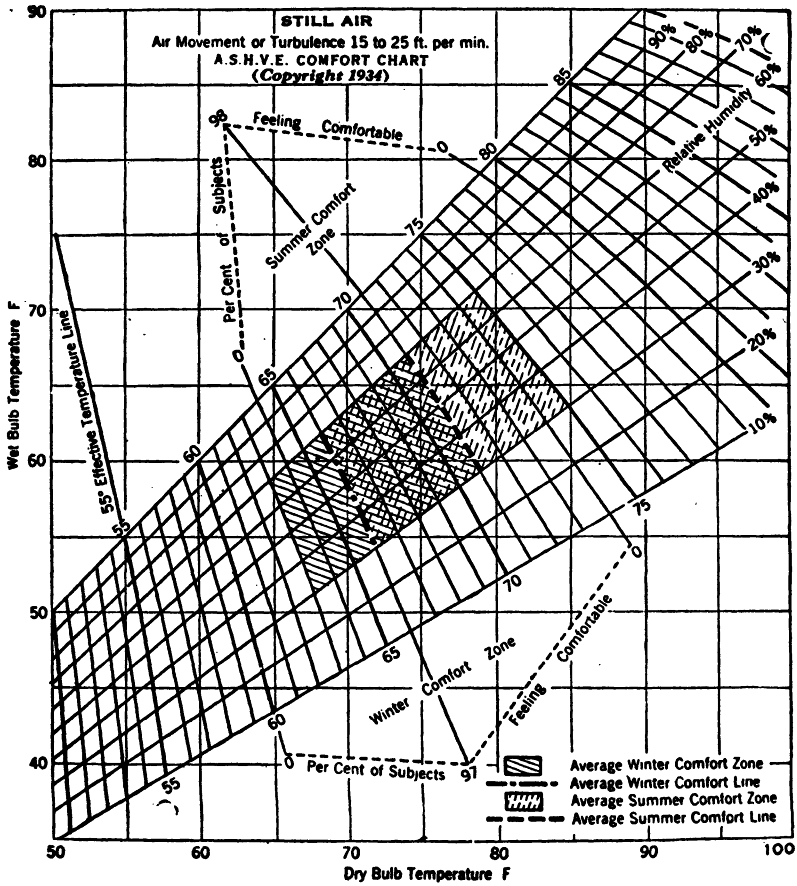
FIG. 1. PSYCHROMETRIC CHART, PERSONS AT REST, NORMALLY CLOTHED, IN STILL AIR,

(*b*) Effective temperatures corresponding to the wet and dry bulb temperatures are also shown and may be used in conjunction with the Comfort Chart (Fig. 2).

Sensations of warmth or cold depend upon the dry and wet bulb temperatures, and also on air motion, so that charts giving effective temperatures (*b*) are drawn for different air velocities.

That shown in Fig. 2 is for still air and is suitable for most indoor conditions.

All of these charts are based on experiments made at Pittsburgh and, as stated in Chapter XI, they may require some slight modification when applied under different climatic conditions.



(*Courtesy of American Society of Heating and Ventilating Engineers*)

FIG. 2. A.S.H.V.E. COMFORT CHART FOR AIR VELOCITIES OF 15 TO 25 FPM (STILL AIR)

The number given to the effective temperature line is the temperature corresponding to complete saturation or 100 per cent relative humidity, so that the dry bulb, wet bulb and effective temperatures coincide at that point. The shaded area on Fig. 2 indicates that the effective comfort zone is limited to humidities from 30 to 70 per cent. Lower or higher relative

humidities are inadvisable. The chart does not apply to rooms heated by radiant methods or to cases where the period of occupancy is short (less than three hours).

Satisfactory comfort conditions for men at work are found to vary from 40° to 70° ET., depending upon the rate of work and amount of clothing worn.[1] In hot industries, 80° ET. is considered the upper limit compatable with efficiency, and, whenever possible, this should be reduced to 70° ET. or less.

[1]Effective Temperature for Persons Lightly Clothed and Working in Still Air, by F. C. Houghton, W. W. Teague and W. E. Miller (A.S.H.V.E. Transactions, Vol. 32, 1926).

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